BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART XXIX. PHYTOPLANKTON OF THE SEASONAL SURVEYS OF 1978 AND 1979, AND FURTHER PRE- vs. POST-OPERATIONAL COMPARISONS AT COOK NUCLEAR PLANT

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Under Contract with:

American Electric Power Service Corporation

Special Report No. 44
of the
Great Lakes Research Division
The University of Michigan

January 1982

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DONALD C. COOK NUCLEAR PLANT

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XXVIII. Entrainment of phytoplankton at the Donald C. Cook Nuclear Plant - 1978. W. Chang, R. Rossmann, J. Pappas, and W. L. Yocum. May 1981. 106 pp., plus Appendix of 3 microfiche cards.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

Our thanks are tendered to a number of persons who have assisted in the carrying out of this study.

To members of the phytoplankton staff who conducted the tedious but essential work of counting and identifying phytoplankton samples, we extend our sincere gratitude; they were: James Barres, Julie Wolin, Robert Genter, and David Farris. One of us (LEF) also participated in this work.

For field assistance rendered by members of the fisheries, benthos, and zooplankton sections, we are grateful.

As always the captain and crew of the R/V MYSIS have provided much appreciated field assistance over and above their mere duty.

Dr. William Chang is gratefully acknowledged for assistance in statistical matters.

INTRODUCTION

The Donald C. Cook Nuclear Plant is located on the southeastern shore of Lake Michigan, in Lake Township, Berrien County, Michigan. The plant is approximately 11 miles south of Benton Harbor and 2 miles north and west of Bridgman, Michigan.

A two-unit electric generating station, the plant is rated at 2,200 megawatts and draws cooling and service water from Lake Michigan through three intake pipes from approximately 2,250 feet offshore in 24 feet of water. The plant employs a once-through cooling system, returning used cooling water to the lake through two diffuser discharge structures located approximately 1,200 feet offshore in 18 feet of water.

Unit 1 began operating in January 1975 and unit 2 in early 1978. With both units at full power the condenser cooling water flow rate is 1,645,000 gpm (3,650 cfs) and the total heat rejection rate is 15.5×10^9 Btu per hour. Unit 1 at full power imparts to the condenser cooling water a temperature rise of 21.8 F°; unit 2 at full power produces a rise of 16.7 F° in its cooling water. Used cooling water from unit 1 returns to the lake through a two-slot diffuser discharge structure; that from unit 2 through a three-slot diffuser discharge structure. The exit velocities at both diffusers are about 13 ft/sec. The discharge velocities create an area of high turbulence in front of each discharge structure. The regions of high turbulence are short-lived, both temporally and spatially, as ambient water is rapidly entrained into the discharged water and the velocity of the discharged water falls quickly to ambient current velocity.

Phytoplankters drawn into the plant with cooling water are subject to

sudden increase in temperature, mauling by pumps, high velocity discharge, and rapid dilution with cooler water.

Operation of the plant, then, has at least the potential of affecting the structure of the phytoplankton community.

The strategy for detecting changes in the phytoplankton community near the Cook Plant involves comparisons of phytoplankton abundances in three depth zones near the plant to abundances in the same three depth zones at distances 2 miles or more away from the plant. In any one survey these comparisons are spatial but, repeated over time, they allow temporal comparisons as well. The temporal comparisons primarily consist of conditions in preoperational years compared against operational years. Conditions in preoperational years provide a measure of natural variation against which variations in operational years may be compared to detect possible plant-related perturbations.

This report serves the double purpose of recording the results of seasonal surveys made in 1978 and 1979 and of reporting additional preoperational vs. postoperational analyses according to the strategy outlined above.

Figure 1 shows the station positions of the present 36-station sampling grid centered on the Cook Plant. This grid, used after April 1972, replaced an earlier 54-station grid. Table 1 compares the two sampling grids and shows the stations dropped and stations retained in changing to the 36-station grid.

At all complete stations in Figure 1 phytoplankton, zooplankton, benthos, and physical measurements are collected during the seasonal surveys. The physical measurements consist of surface-water temperature, water depth, Secchi disc water transparency, and water color as seen above the white 20-cm Secchi disc, as well as weather conditions and wind and wave characteristics. The seasonal physical data are given in Appendix A.

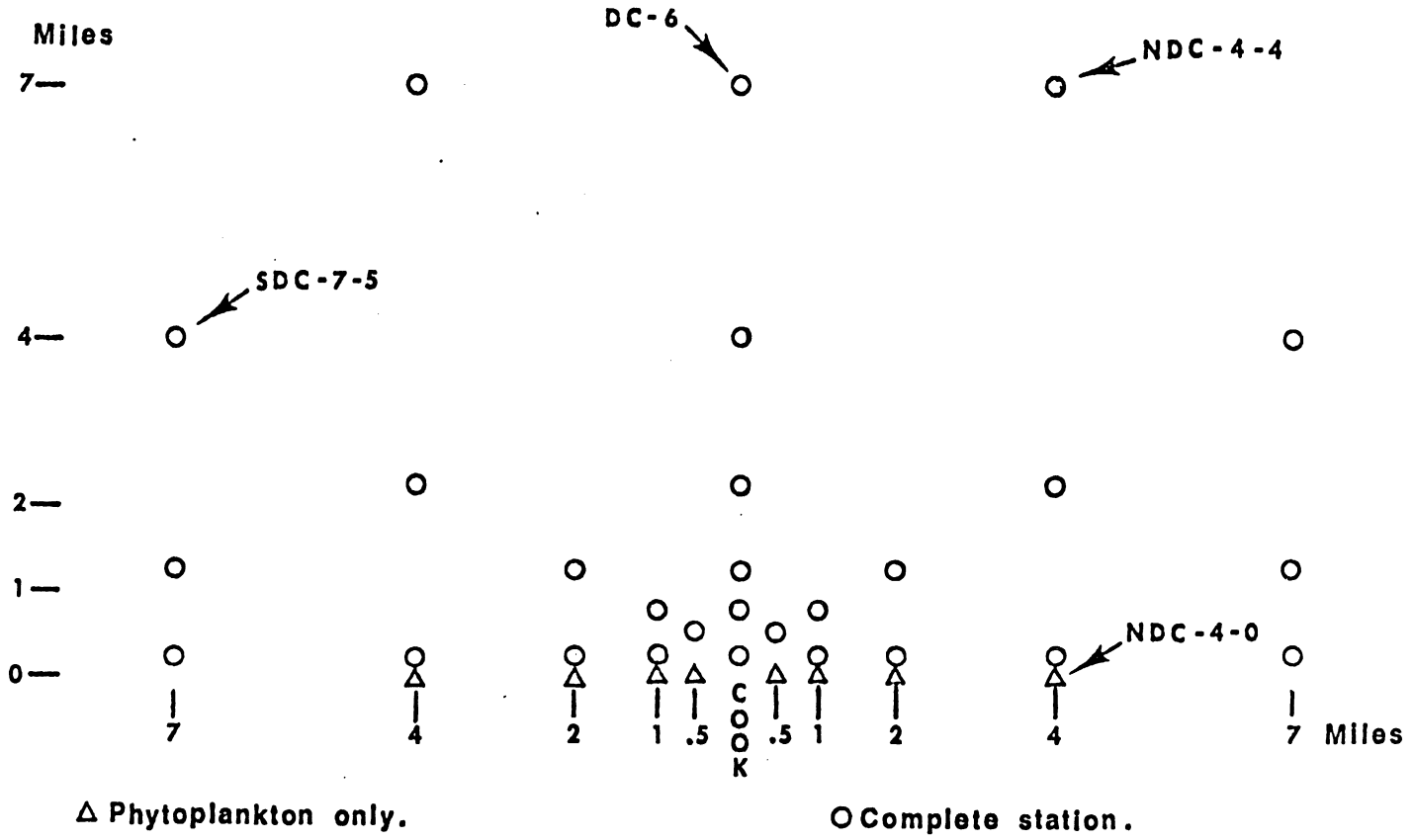

FIG. 1. The present 36-station Cook Plant sampling grid, used since April of 1972. The stations are designated as follows: SDC stations are located south of the plant, NDC stations are north of the plant, and DC stations are directly offshore of the plant. The first number in the designation is the number of miles north or south of the plant. The second number is the serial number of the station from shore lakeward. The serial number of the phytoplankton-only stations is 0.

TABLE 1. Comparison of the original 54-station seasonal sampling grid to the 36-station sampling grid which was instituted in the April 1972 seasonal survey at Cook Plant. X denotes a retained station. -- denotes an omitted station.

Station	54-station grid	36-station grid	Station	54-station grid	36-station grid
DC-1	X	X	NDC-7-3	X	X
DC-2	X	X	NDC-7-4	X	--
DC-3	X	X	NDC-7-5	X	X
DC-4	X	X	SDC-.25-1	X	--
DC-5	X	X	SDC-.5-0	X	X
DC-6	X	X	SDC-.5-1	X	--*
NDC-.25-1	X	--	SDC-.5-2	X	X
NDC-.5-0	X	X	SDC-.5-3	X	--
NDC-.5-1	X	--*	SDC-1-0	X	X
NDC-.5-2	X	X	SDC-1-1	X	X
NDC-.5-3	X	--	SDC-1-2	X	X
NDC-1-0	X	X	SDC-1-3	X	--
NDC-1-1	X	X	SDC-2-0	X	X
NDC-1-2	X	X	SDC-2-1	X	X
NDC-1-3	X	--	SDC-2-2	X	--
NDC-2-0	X	X	SDC-2-3	X	X
NDC-2-1	X	X	SDC-2-4	X	--
NDC-2-2	X	--	SDC-4-0	X	X
NDC-2-3	X	X	SDC-4-1	X	X
NDC-2-4	X	--	SDC-4-2	X	--
NDC-4-0	X	X	SDC-4-3	X	X
NDC-4-1	X	X	SDC-4-4	X	X
NDC-4-2	X	--	SDC-7-1	X	X
NDC-4-3	X	X	SDC-7-2	X	--
NDC-4-4	X	X	SDC-7-3	X	X
NDC-7-1	X	X	SDC-7-4	X	--
NDC-7-2	X	--	SDC-7-5	X	X

*Sampled occasionally in the years since 1972.

Occasionally weather or logistical difficulties result in some stations of a survey being taken a day ahead of or a day later than the bulk of the stations. This results in different dates on the phytoplankton station collection sheets which are reproduced in Appendix B. It has been our custom to use the day when the bulk of the stations were taken as the date of the survey.

Parts of the material presented here have been used by the Indiana & Michigan Electric Company in their Cook Plant Annual Environmental Operating Reports. Other parts, including the appendices of physical data, phytoplankton station collections, and master lists of phytoplankton collected, were not in the company report and have been added. The master lists of phytoplankton collected constitute Appendix C.

TECHNIQUES

Phytoplankton samples are collected by Niskin bottle from a depth of 1 m, with the exception of the nearshore stations. Nearshore collections (serial number zero stations) are made by submerging an open 1-liter bottle 4 inches below the water surface. All samples are 1-liter whole samples. Each sample is fixed with Utermohl's iodine fixative immediately after collection and stored in an opaque container.

In the laboratory, each sample is concentrated to 100 mL by settling in a 1,000-mL graduate cylinder and siphoning off 900 mL of fluid. The concentrated sample is stored in a 100-mL opaque bottle.

The samples of 1971 and of April 1972 were prepared and counted by the Utermohl technique: placing an aliquot of the concentrated sample in a tubular combination settling and counting chamber and allowing the aliquot to settle overnight. The counting chamber containing the settled cells was then separated

from the settling chamber, covered, and placed on the microscope. The samples were counted on a binocular inverted microscope at 1,000X magnification.

Beginning with July 1972, and continuing since, the method of concentration for species identification and enumeration has been the settle-freeze method as proposed by Sanford et al. (1969). The method entails 2 days' settling of 1,000 mL of sample in a graduated cylinder. On the third day the top 900 mL are siphoned off and discarded. Part of the remaining 100 mL is used for preparation for the microscope slide and the rest is kept for any possible further references or back checking.

The once-settled sample is then diluted if need be and settled again, this time in 18-mL cylinders. These cylinders are attached with a small amount of stopcock lubricant (to prevent leakage) to the microscope slides which rest on an aluminum plate one quarter inch thick. The whole apparatus is then secured together mechanically. The microscope slides, prior to having the cylinders placed on them, were treated with Dessicote to provide a hydrophobic surface to the slide. After the samples have settled overnight, the aluminum plate on which they rest is placed on a block of dry ice for 90 seconds or less. This freezes the bottom 1-1.5 mL. The unfrozen part is then discarded and the cylinders are removed from the slides. The slides are then placed in an anhydrous ethanol chamber for 2 days, and then in a toluene chamber for 2 days.

The first chamber removes the excess water and the second prepares the samples for their final mounting in toluene-based Permount®. One drop of Permount® is put on the slide, a cover slip is then placed over it, and the slide is allowed to dry for 2 days or more.

The specimens are counted, at 1,200X under oil immersion on a Leitz Ortholux microscope, to species, variety, and form when practical, otherwise to genus

or group. Only those specimens that appear to have been viable at the time of collection are counted. Two sweeps of the slide are made, one vertical and one horizontal. This provides an indication of the randomness of the species on the slide.

All species are counted to individual cells, except for filamentous blue-green algae with cylindrical trichomes which are counted as individual organisms. Prior to 1974 all colonial blue-greens were counted as single organisms; the change in counting resulted in an apparent increase of blue-greens beginning in 1974.

Phytoplankton abundances derived from the counts are calculated as cells per liter, but are divided by 1,000 in the computer print-outs.

Species and forms are presented in the way in which they are recognized and counted. Examples are: The flagellate Cryptomonas is recognized and counted separately from unidentified "Flagellates"; Anacystis and Chroococcus are no longer recognized as separate entities, but counted together as Anacystis in accordance with Drouet's (1968) revision of blue-green taxonomy.

RESULTS AND DISCUSSIONS

The authors believe that the materials presented in this section will be more convenient for both authors and readers if presentation of the results and discussion of the results are not separated. We believe that the reader will have no difficulty in distinguishing between the objective presentation of the results and our subjective discussion of them.

Phytoplankton Summary Tables

The phytoplankton summary tables employed here are based on the ones used by the Michigan Water Resources Commission at the time our reporting procedures

were established (MWRC 1970). Our summaries differ from theirs in that we count the numbers of cells in filamentous and colonial forms (except blue-green algae with cylindrical trichomes which are counted as individual organisms), while the Commission counts a filament or colony as a single organism. The station collection records from which the summaries were prepared constitute Appendix B.

The summary table for each seasonal survey presents, station-by-station, the surface-water temperature at the time of collection, the numbers per mL of each of ten major categories of planktonic algae, and the dominant (and codominant, see below) species or groups. The categories of phytoplankton employed are: coccoid blue-green algae, filamentous blue-green algae, coccoid green algae, filamentous green algae, flagellates, centric diatoms, pennate diatoms, desmids, other algae, and total algae. The summary tables allow quick assessment of the general compositions of the populations sampled, the ambient water temperature, and give the dominant and codominant species or groups (forms). The summary tables presented in Table 2 cover the surveys of spring (April), summer (July), and fall (October) of 1978 and 1979.

Dominant and Codominant Phytoplankters

In each phytoplankton sample, one form (species or group) is typically present in greater abundance than the others. We designate these species or groups as "dominant." In many samples, however, one or more other species or groups will come close to matching the numbers of the dominant form; we designate these slightly less abundant forms "codominants" and list them along with the dominant in the "Dominant species" column of Table 2.

In Table 3 the dominant and codominant forms in the station collections of each seasonal survey of 1970 through 1979 have been assembled and the numbers of

TABLE 2. Phytoplankton summary tables. Surface water temperature in °C and densities (cells/ml) of major phytoplankton groups.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
14 APRIL 1978												
DC-0	5.0	82.9	23.2	262.0	0.0	1233.6	1402.7	955.0	0.0	112.7	4072.2	Flagellates
DC-1	6.1	381.4	3.3	92.9	0.0	911.9	848.9	570.4	0.0	56.4	2865.1	Flagellates *Anacystis incerta*
DC-2	6.2	0.0	3.3	129.3	0.0	1638.2	1518.8	782.6	0.0	49.7	4121.9	Flagellates
DC-3	4.2	0.0	23.2	112.7	0.0	1581.8	981.6	636.7	0.0	29.8	3365.9	Flagellates
DC-4	3.9	0.0	3.3	34.8	0.0	905.3	383.0	252.0	0.0	28.2	1606.7	*Ochromonas* sp. Flagellates
DC-5	2.8	0.0	1.7	21.6	0.0	741.2	404.6	102.8	0.0	41.5	1313.2	Flagellates
DC-6	1.8	190.7	0.0	9.9	0.0	754.4	567.1	184.0	1.7	34.8	1742.6	Flagellates
NDC-.5-0	4.0	46.4	0.0	245.4	0.0	606.9	1197.1	819.1	0.0	19.9	2934.8	Flagellates *Stephanodiscus* sp. *Stephanodiscus* sp. #5
NDC-.5-1	6.0	39.8	0.0	132.6	46.4	1943.3	1462.4	1107.6	3.3	69.6	4805.1	Flagellates
NDC-.5-2	5.8	0.0	3.3	119.4	0.0	1561.9	911.9	606.9	0.0	49.7	3253.1	Flagellates *Ochromonas* sp.
NDC-1-0	5.0	53.1	3.3	212.2	0.0	1306.6	2022.8	1432.6	0.0	86.2	5116.8	Flagellates *Stephanodiscus* sp. #5
NDC-1-1	6.0	0.0	6.6	159.2	0.0	1303.2	1313.2	540.5	0.0	66.3	3389.1	Flagellates *Ochromonas* sp. *Stephanodiscus* sp. #5
NDC-1-2	4.4	0.0	0.0	96.2	6.6	1880.2	1389.5	596.9	0.0	69.6	4039.0	*Ochromonas* sp.
NDC-2-0	4.0	39.8	3.3	53.1	0.0	560.4	1263.4	955.0	0.0	6.6	2881.7	*Stephanodiscus* sp. #5 Flagellates
NDC-2-1	6.0	348.2	13.3	139.3	3.3	1651.4	1744.3	1306.6	3.3	96.2	5305.8	*Stephanodiscus* sp. Flagellates
NDC-2-3	3.9	0.0	3.3	92.9	13.3	2079.2	955.0	298.5	0.0	102.8	3544.9	*Ochromonas* sp. Flagellates
NDC-4-0	---	13.3	9.9	175.8	0.0	580.3	892.0	1018.1	0.0	13.3	2702.6	Flagellates
NDC-4-1	5.2	0.0	3.3	155.9	0.0	1717.8	1498.9	822.4	0.0	89.5	4287.8	*Ochromonas* sp. Flagellates
NDC-4-3	3.2	0.0	6.6	53.1	0.0	1217.0	785.9	378.0	0.0	43.1	2483.8	*Ochromonas* sp.
NDC-4-4	2.0	77.9	5.0	28.2	1.7	1142.4	693.1	199.0	0.0	58.0	2205.2	Flagellates
NDC-7-1	6.0	437.7	6.6	73.0	13.3	1203.8	858.9	776.0	0.0	66.3	3435.5	*Ochromonas* sp. Flagellates
NDC-7-3	4.0	99.5	6.6	116.1	0.0	1870.3	1290.0	802.5	3.3	36.5	4224.7	*Ochromonas* sp. Flagellates *Stephanodiscus* sp. #5
NDC-7-5	2.4	0.0	3.3	23.2	9.9	1452.5	563.7	205.6	0.0	39.8	2298.1	Flagellates *Ochromonas* sp.
SDC-.5-0	4.0	0.0	3.3	1671.3	0.0	1386.1	2258.3	1518.8	3.3	46.4	6887.6	Unknown coccoid green
SDC-.5-1	6.0	0.0	0.0	291.8	0.0	1210.4	1459.1	1004.8	0.0	69.6	4035.7	Flagellates *Stephanodiscus* sp. *Stephanodiscus* sp. #5

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
14 APRIL 1978 continued.												
SDC-.5-2	6.8	0.0	0.0	262.0	0.0	948.4	669.9	567.1	0.0	13.3	2460.6	Flagellates
SDC-1-0	4.0	0.0	0.0	1227.0	0.0	600.2	1018.1	643.3	0.0	13.3	3501.8	Unknown coccoid green
SDC-1-1	5.5	66.3	0.0	331.6	0.0	1150.7	716.3	845.6	0.0	3.3	3113.8	Flagellates
SDC-1-2	4.9	0.0	0.0	102.8	0.0	528.9	487.5	669.9	0.0	29.8	1818.9	Flagellates Fragilaria crotonensis Stephanodiscus sp. Asterionella formosa
SDC-2-0	4.0	0.0	0.0	1853.7	0.0	908.6	1064.5	779.3	0.0	43.1	4649.2	Unknown coccoid green
SDC-2-1	5.8	0.0	0.0	155.9	0.0	1120.9	1170.6	842.3	0.0	9.9	3299.5	Flagellates
SDC-2-3	4.0	6.6	0.0	111.1	0.0	1565.2	563.7	512.3	0.0	24.9	2783.9	Ochromonas sp. Flagellates
SDC-4-0	3.0	411.2	0.0	285.2	0.0	736.2	1230.3	1412.7	0.0	23.2	4098.7	Flagellates Anacystis incerta Stephanodiscus sp. Fragilaria crotonensis
SDC-4-1	5.7	0.0	6.6	106.1	0.0	1326.5	1084.4	1177.2	0.0	66.3	3767.1	Flagellates
SDC-4-3	4.0	149.2	1.7	18.2	0.0	872.1	583.6	336.6	0.0	38.1	1999.6	Flagellates
SDC-4-4	1.7	0.0	0.0	79.6	0.0	923.5	328.3	114.4	0.0	1.7	1447.5	Flagellates
SDC-7-1	5.8	136.0	6.6	172.4	0.0	1336.4	656.6	1263.4	0.0	116.1	3687.5	Flagellates Fragilaria crotonensis Asterionella formosa
SDC-7-3	4.8	0.0	6.6	136.0	13.3	855.6	832.3	1157.3	0.0	46.4	3047.5	Flagellates Asterionella formosa Fragilaria crotonensis
SDC-7-5	3.2	0.0	6.6	73.0	0.0	1077.7	613.5	460.9	0.0	26.5	2258.3	Flagellates
12 JULY 1978												
DC-0	14.5	165.8	431.1	517.3	73.0	1651.4	7348.5	8542.3	33.2	908.6	19671.3	Melosira granulata Fragilaria crotonensis
DC-1	11.0	1293.3	82.9	56.4	76.3	2162.1	1525.4	2659.5	0.0	139.3	7995.2	Tabellaria fenestrata v. intermedia Chrysophycean flagellate spp. Anacystis incerta
DC-2	9.9	331.6	39.8	29.8	3.3	878.8	606.9	464.3	0.0	331.6	2686.1	Flagellates
DC-3	9.9	348.2	61.3	86.2	0.0	582.0	349.9	805.8	0.0	36.5	2269.9	Fragilaria crotonensis Anacystis incerta Flagellates
DC-4	11.8	149.2	11.6	31.5	18.2	645.0	550.5	487.5	3.3	218.9	2115.7	Flagellates
DC-5	16.1	0.0	39.8	89.5	23.2	1343.0	238.8	281.9	0.0	119.4	2135.6	Flagellates

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
12 JULY 1978 continued.												
DC-6	18.9	0.0	29.8	13.3	39.8	1668.0	69.6	630.1	0.0	86.2	2536.8	Chrysophycean flagellate spp. Flagellates
NDC-.5-0	15.0	530.6	92.9	484.2	0.0	968.3	7567.4	9736.1	26.5	1127.5	20533.5	Melosira granulata Fragilaria crotonensis
NDC-.5-1	10.8	49.7	96.2	13.3	0.0	713.0	580.3	951.7	0.0	76.3	2480.5	Fragilaria crotonensis Tabellaria fenestrata v. intermedia Flagellates
NDC-.5-2	10.0	663.2	36.5	0.0	3.3	882.1	722.9	583.6	3.3	321.7	3216.6	Anacystis incerta Flagellates
NDC-1-0	14.4	2984.5	165.8	152.5	39.8	106.1	6605.7	7713.3	6.6	543.8	18318.3	Anacystis incerta Fragilaria crotonensis Melosira granulata
NDC-1-1	8.2	1857.0	129.3	63.0	0.0	825.7	596.9	888.7	3.3	132.6	4496.7	Anacystis incerta
NDC-1-2	8.5	0.0	23.2	0.0	23.2	892.0	444.4	351.5	0.0	311.7	2046.1	Flagellates
NDC-2-0	16.0	1857.0	6.6	517.3	33.2	278.6	9610.1	13523.2	19.9	762.7	26608.6	Melosira granulata Fragilaria crotonensis
NDC-2-1	8.0	1107.6	152.5	112.7	16.6	2331.2	776.0	1130.8	0.0	480.8	6108.3	Flagellates Anacystis incerta
NDC-2-3	9.7	265.3	59.7	152.5	19.9	1916.7	935.1	1001.5	9.9	626.7	4987.4	Flagellates
NDC-4-0	16.0	3283.0	73.0	92.9	33.2	543.8	8834.2	11712.6	0.0	431.1	25003.6	Fragilaria crotonensis Melosira granulata
NDC-4-1	7.1	994.8	288.5	145.9	109.4	2397.6	1041.3	1439.2	9.9	898.7	7325.3	Flagellates
NDC-4-3	10.0	86.2	79.6	122.7	3.3	1263.4	646.6	693.1	3.3	563.7	3462.0	Flagellates
NDC-4-4	18.4	0.0	119.4	9.9	13.3	2052.7	152.5	1661.4	0.0	86.2	4095.4	Fragilaria crotonensis
NDC-7-1	10.0	0.0	76.3	76.3	23.2	895.4	567.1	437.7	0.0	394.6	2470.5	Flagellates
NDC-7-3	11.1	187.4	66.3	348.2	23.2	1313.2	683.1	565.4	8.3	530.6	3725.7	Flagellates
NDC-7-5	17.0	0.0	9.9	378.0	29.8	1837.1	507.4	782.6	0.0	179.1	3724.0	Flagellates Chrysophycean flagellate spp.
SDC-.5-0	14.5	1724.4	1154.0	278.6	26.5	1485.6	12733.9	14219.6	13.3	795.9	32431.7	Melosira granulata Fragilaria crotonensis
SDC-.5-1	8.0	205.6	29.8	169.1	0.0	1442.5	590.3	474.2	3.3	441.0	3355.9	Flagellates
SDC-.5-2	7.7	59.7	61.3	69.6	9.9	1033.0	381.4	950.1	5.0	247.1	2817.0	Flagellates
SDC-1-0	13.8	106.1	0.0	437.7	26.5	1054.5	6141.5	8456.1	6.6	179.1	16408.2	Fragilaria crotonensis Melosira granulata
SDC-1-1	8.1	0.0	79.6	36.5	29.8	1850.4	577.0	1150.7	0.0	507.4	4231.4	Flagellates
SDC-1-2	8.3	447.7	449.3	101.1	9.9	839.0	688.1	1366.2	1.7	170.8	4073.9	Tabellaria fenestrata v. intermedia Flagellates Anacystis incerta Anabaena flos-aquae
SDC-2-0	11.5	397.9	663.2	968.3	13.3	2467.2	10160.6	19671.3	39.8	795.9	35177.5	Tabellaria fenestrata v. intermedia Fragilaria crotonensis Melosira granulata

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
12 JULY 1978 continued.												
SDC-2-1	8.1	331.6	66.3	79.6	29.8	2105.7	802.5	1701.2	6.6	401.3	5524.7	Flagellates
SDC-2-3	11.8	351.1	16.6	9.9	9.9	958.4	325.0	218.9	0.0	305.1	2195.3	Flagellates
SDC-4-0	11.5	1989.7	132.6	145.9	0.0	888.7	6048.6	11274.8	0.0	663.2	21143.6	Anacystis cyanea Fragilaria crotonensis Anacystis incerta Tabellaria fenestrata v. intermedia Stephanodiscus sp.
SDC-4-1	8.8	729.5	162.5	162.5	29.8	2211.9	507.4	1197.1	0.0	683.1	5683.8	Flagellates
SDC-4-3	14.0	0.0	26.5	179.1	23.2	2109.1	726.2	789.2	3.3	391.3	4248.0	Flagellates Chrysophycean flagellate spp.
SDC-4-4	18.3	132.6	205.6	82.9	63.0	1691.2	112.7	981.6	3.3	76.3	3349.3	Fragilaria crotonensis Flagellates Chrysophycean flagellate spp.
SDC-7-1	9.0	132.6	404.6	86.2	29.8	2832.0	885.4	2530.2	6.6	577.0	7484.5	Tabellaria fenestrata v. intermedia Flagellates
SDC-7-3	12.8	358.1	56.4	182.4	53.1	1051.2	454.3	945.1	0.0	202.3	3302.9	Flagellates
SDC-7-5	17.3	0.0	1736.0	31.5	23.2	585.3	86.2	1222.0	6.6	31.5	3722.4	Anabaena flos-aquae
11 OCTOBER 1978												
DC-0	16.2	7136.3	119.4	1359.6	0.0	325.0	4629.3	2672.8	0.0	1140.7	17383.1	Anacystis incerta
DC-1	19.2	4324.2	331.6	305.1	3.3	865.5	766.0	822.4	3.3	172.4	7593.9	Anacystis incerta
DC-2	17.8	1346.3	46.4	46.4	6.6	504.1	341.6	258.7	0.0	49.7	2599.8	Anacystis incerta Gomphosphaeria lacustris
DC-3	16.0	835.7	23.2	92.9	0.0	623.4	212.2	295.1	0.0	129.3	2211.9	Gomphosphaeria lacustris
DC-4	15.5	761.1	126.0	116.1	0.0	323.3	29.8	89.5	1.7	0.0	1447.5	Anacystis incerta
DC-5	15.5	3725.7	0.0	58.0	0.0	641.7	51.4	59.7	0.0	54.7	4591.2	Anacystis incerta
DC-6	15.1	1399.4	41.5	87.9	3.3	784.3	54.7	8.3	1.7	109.4	2490.4	Anacystis incerta
NDC-.5-0	16.0	6177.9	92.9	563.7	0.0	424.5	2715.9	1518.8	0.0	686.4	12180.1	Anacystis incerta
NDC-.5-1	17.0	4891.3	3.3	749.4	0.0	921.9	427.8	334.9	0.0	235.4	7564.1	Anacystis incerta
NDC-.5-2	16.8	1124.2	39.8	36.5	0.0	996.5	311.7	165.8	0.0	97.8	2772.3	Anacystis incerta
NDC-1-0	16.5	4463.5	199.0	676.5	13.3	1001.5	1873.6	1057.8	0.0	583.6	9868.8	Anacystis incerta
NDC-1-1	16.0	4987.5	487.5	252.0	3.3	1343.0	928.5	1154.0	13.3	288.5	9457.6	Anacystis incerta
NDC-1-2	16.0	10107.6	245.4	487.5	6.6	1313.2	650.0	759.4	0.0	291.8	13861.4	Anacystis incerta
NDC-2-0	17.0	4211.5	129.3	374.7	3.3	411.2	1014.7	921.9	6.6	218.9	7292.1	Anacystis incerta
NDC-2-1	16.0	5217.9	117.7	232.1	11.6	857.2	640.0	334.9	0.0	205.6	7617.1	Anacystis incerta
NDC-2-3	15.3	1396.1	46.4	26.5	0.0	600.2	305.1	169.1	0.0	86.2	2629.7	Anacystis incerta

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
11 OCTOBER 1978 continued.												
NDC-4-0	14.0	2367.7	49.7	908.6	3.3	998.2	2148.9	616.8	0.0	560.4	7653.6	Anacystis incerta Melosira granulata
NDC-4-1	15.7	2162.1	195.7	371.4	19.9	1230.3	792.6	527.3	3.3	321.7	5624.1	Anacystis incerta
NDC-4-3	15.0	436.1	73.0	26.5	1.7	701.4	169.1	61.3	0.0	51.4	1520.4	Anacystis incerta Flagellates
NDC-4-4	14.0	6385.2	137.6	92.9	1.7	822.4	66.3	97.8	0.0	23.2	7627.1	Rhodomonas minuta Anacystis incerta
NDC-7-1	15.3	2775.6	126.0	444.4	0.0	762.7	1081.1	567.1	0.0	145.9	5902.7	Gomphosphaeria lacustris
NDC-7-3	15.0	4735.4	157.5	174.1	19.9	1162.3	973.3	379.7	0.0	313.4	7915.6	Anacystis incerta
NDC-7-5	15.5	2636.3	1.7	26.5	0.0	883.7	159.2	89.5	1.7	53.1	3851.7	Gomphosphaeria lacustris Anacystis incerta
SDC-.5-0	15.6	4728.8	149.2	1164.0	6.6	401.3	3458.7	1605.0	9.9	941.8	12465.3	Gomphosphaeria lacustris Anacystis incerta
SDC-.5-1	16.0	3259.8	160.8	114.4	0.0	900.3	288.5	253.7	0.0	136.0	5113.5	Melosira granulata Gomphosphaeria lacustris
SDC-.5-2	16.5	3438.8	33.2	169.1	0.0	931.8	577.0	325.0	0.0	189.0	5663.9	Anacystis incerta Anacystis incerta
SDC-1-0	15.6	1087.7	26.5	517.3	16.6	129.3	1240.2	626.7	6.6	275.2	3926.3	Anacystis incerta
SDC-1-1	14.7	1979.7	397.9	202.3	0.0	1047.9	441.0	384.7	0.0	285.2	4738.7	Anacystis incerta
SDC-1-2	15.8	3554.9	6.6	258.7	0.0	965.0	424.5	474.2	3.3	155.9	5843.0	Anacystis incerta
SDC-2-0	15.2	935.1	159.2	218.9	0.0	563.7	1757.5	656.6	0.0	165.8	4456.9	Melosira granulata Anacystis incerta
SDC-2-1	15.1	1857.0	56.4	325.0	9.9	945.1	474.2	540.5	0.0	136.0	4344.1	Anacystis incerta
SDC-2-3	15.9	1705.3	14.9	44.8	0.0	380.5	86.2	148.4	0.8	19.1	2400.0	Anacystis incerta
SDC-4-0	15.6	4045.7	212.2	1286.7	6.6	404.6	1983.0	1293.3	0.0	722.9	9955.0	Anacystis incerta
SDC-4-1	15.0	3087.3	0.0	265.3	0.0	785.9	633.4	653.3	0.0	122.7	5547.9	Anacystis incerta
SDC-4-3	15.7	2918.2	308.4	26.5	0.0	878.8	242.1	96.2	0.0	73.0	4543.1	Gomphosphaeria lacustris Anacystis incerta
SDC-4-4	14.5	3955.3	126.0	203.1	0.0	407.1	31.5	18.2	0.0	40.6	4781.8	Anacystis incerta
SDC-7-1	15.0	1051.2	19.9	338.2	0.0	905.3	550.5	480.8	0.0	315.0	3661.0	Anacystis incerta
SDC-7-3	15.2	887.1	69.6	114.4	0.0	301.8	76.3	431.1	0.0	56.4	1936.6	Anacystis incerta
SDC-7-5	15.2	7738.2	325.0	89.5	0.0	683.1	26.5	99.5	1.7	112.7	9076.2	Anacystis incerta
12 APRIL 1979												
DC-0	4.2	0.0	0.0	39.8	0.0	278.6	2487.1	1008.1	0.0	39.8	3853.3	Stephanodiscus hantzschii
DC-1	5.1	26.5	6.6	126.0	0.0	411.2	2394.2	795.9	0.0	19.9	3780.4	Stephanodiscus hantzschii
DC-2	3.5	0.0	0.0	46.4	3.3	208.9	2036.1	669.9	0.0	33.2	2997.8	Stephanodiscus hantzschii
DC-3	3.5	0.0	0.0	86.2	0.0	590.3	2308.0	623.4	0.0	119.4	3727.3	Stephanodiscus hantzschii

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
12 APRIL 1979 continued.												
DC-4	3.0	570.4	0.0	59.7	0.0	656.6	1452.5	749.4	0.0	46.4	3535.0	Asterionella formosa Gomphosphaeria lacustris
DC-5	1.9	0.0	0.0	66.3	0.0	364.8	842.3	673.2	0.0	39.8	1986.4	Asterionella formosa
DC-6	1.3	0.0	0.0	36.5	0.0	623.4	530.6	187.4	1.7	38.1	1417.6	Flagellates Ochromonas sp.
NDC-.5-0	3.8	132.6	0.0	49.7	0.0	368.1	1678.0	470.9	0.0	56.4	2755.7	Stephanodiscus sp.
NDC-.5-1	3.8	0.0	0.0	484.2	129.3	789.2	4387.2	1638.2	0.0	109.4	7537.5	Stephanodiscus hantzschii Stephanodiscus sp. Asterionella formosa
NDC-.5-2	3.6	0.0	0.0	159.2	0.0	729.5	2977.9	1207.1	0.0	106.1	5179.8	Stephanodiscus hantzschii
NDC-1-0	4.0	0.0	0.0	23.2	0.0	195.7	1999.6	577.0	0.0	16.6	2812.1	Stephanodiscus sp. Stephanodiscus hantzschii
NDC-1-1	4.1	0.0	0.0	142.6	0.0	507.4	3077.4	769.3	0.0	63.0	4559.7	Stephanodiscus hantzschii
NDC-1-2	3.5	0.0	0.0	73.0	0.0	500.7	1777.4	421.1	0.0	63.0	2835.3	Stephanodiscus hantzschii
NDC-2-0	4.0	53.1	6.6	265.3	0.0	1512.2	6015.5	2109.1	0.0	86.2	10047.9	Stephanodiscus hantzschii Stephanodiscus sp.
NDC-2-1	3.8	0.0	0.0	145.9	0.0	888.7	5149.9	1631.5	0.0	149.2	7965.3	Stephanodiscus hantzschii
NDC-2-3	3.2	0.0	0.0	79.6	39.8	713.0	2981.2	1379.5	0.0	59.7	5252.7	Stephanodiscus hantzschii
NDC-4-0	4.0	530.6	6.6	179.1	0.0	1041.3	5047.1	1910.1	6.6	152.5	8873.9	Stephanodiscus hantzschii Stephanodiscus sp.
NDC-4-1	3.8	0.0	0.0	288.5	16.6	832.3	5040.5	1717.8	0.0	99.5	7995.2	Stephanodiscus hantzschii
NDC-4-3	2.9	0.0	16.6	56.4	0.0	756.1	2089.2	1435.9	0.0	13.3	4367.3	Asterionella formosa Stephanodiscus hantzschii
NDC-4-4	1.4	0.0	0.0	13.3	0.0	1183.9	391.3	242.1	0.0	33.2	1863.7	Flagellates Ochromonas sp.
NDC-7-1	4.1	0.0	0.0	73.0	0.0	288.5	2006.3	1227.0	3.3	13.3	3611.3	Asterionella formosa Stephanodiscus hantzschii
NDC-7-3	3.5	0.0	6.6	149.2	0.0	1021.4	2759.0	1197.1	0.0	23.2	5156.6	Stephanodiscus hantzschii Asterionella formosa Stephanodiscus sp.
NDC-7-5	2.3	26.5	3.3	69.6	0.0	1227.0	1830.5	1416.0	0.0	96.2	4669.1	Asterionella formosa
SDC-.5-0	4.0	0.0	6.6	152.5	6.6	298.5	1989.7	1797.3	0.0	0.0	4251.3	Asterionella formosa
SDC-.5-1	4.9	0.0	0.0	86.2	0.0	520.6	1953.2	441.0	0.0	82.9	3084.0	Stephanodiscus hantzschii
SDC-.5-2	5.6	13.3	0.0	136.0	3.3	1183.9	5869.5	1422.6	6.6	145.9	8781.1	Stephanodiscus hantzschii
SDC-1-0	3.8	0.0	6.6	112.7	0.0	590.3	2699.3	1213.7	13.3	106.1	4742.1	Stephanodiscus hantzschii Asterionella formosa Stephanodiscus sp.
SDC-1-1	5.2	0.0	9.9	56.4	3.3	394.6	2361.1	1651.4	0.0	9.9	4486.7	Asterionella formosa
SDC-1-2	3.8	0.0	0.0	155.9	0.0	1200.4	4068.9	1787.4	0.0	136.0	7348.5	Stephanodiscus hantzschii Asterionella formosa

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
12 APRIL 1979 continued.												
SDC-2-0	3.8	165.8	0.0	99.5	0.0	1041.3	3860.0	2825.3	0.0	99.5	8091.3	Asterionella formosa
SDC-2-1	5.6	464.3	9.9	76.3	9.9	769.3	3256.4	1024.7	0.0	102.8	5713.7	Stephanodiscus hantzschii
SDC-2-3	3.5	663.2	3.3	59.7	0.0	643.3	1217.0	557.1	3.3	76.3	3223.3	Stephanodiscus sp. Anacystis incerta
SDC-4-0	3.5	199.0	6.6	165.8	13.3	1001.5	3700.8	2274.9	0.0	39.8	7401.6	Asterionella formosa Asterionella formosa Stephanodiscus alpinus
SDC-4-1	6.1	0.0	3.3	14.9	5.0	124.4	500.7	242.1	0.0	14.9	905.3	Stephanodiscus sp. Stephanodiscus sp. Asterionella formosa
SDC-4-3	3.1	0.0	3.3	16.6	0.0	437.7	1028.0	1144.1	0.0	46.4	2676.1	Stephanodiscus hantzschii Asterionella formosa
SDC-4-4	1.5	0.0	0.0	9.9	0.0	961.7	504.1	348.2	0.0	86.2	1910.1	Flagellates
SDC-7-1	5.5	0.0	0.0	53.1	0.0	351.5	1233.6	713.0	3.3	36.5	2390.9	Stephanodiscus hantzschii Asterionella formosa
SDC-7-3	4.2	0.0	6.6	66.3	0.0	394.6	782.6	1210.4	6.6	132.6	2599.8	Stephanodiscus sp. Asterionella formosa
SDC-7-5	2.5	199.0	0.0	28.2	0.0	1160.6	470.9	449.3	1.7	39.8	2349.5	Ochromonas sp. Flagellates Asterionella formosa
11 JULY 1979												
DC-0	21.8	0.0	3886.5	809.1	0.0	3103.9	3634.5	5000.7	13.3	955.0	17403.0	Anabaena flos-aquae
DC-1	19.9	199.0	1532.1	112.7	3.3	984.9	96.2	301.8	6.6	89.5	3326.1	Anabaena flos-aquae
DC-2	20.2	99.5	809.1	23.2	0.0	633.4	116.1	338.2	0.0	28.2	2047.7	Anabaena flos-aquae
DC-3	20.9	116.1	945.1	119.4	6.6	739.5	104.5	323.3	0.0	101.1	2455.6	Anabaena flos-aquae
DC-4	20.0	0.0	1493.9	43.1	0.0	852.2	121.0	159.2	0.0	23.2	2692.7	Anabaena flos-aquae
DC-5	20.4	0.0	998.2	39.8	0.0	402.9	112.7	84.6	3.3	24.9	1666.4	Anabaena flos-aquae
DC-6	24.0	132.6	199.0	59.7	0.0	407.9	134.3	278.6	0.0	21.6	1233.6	Fragilaria crotonensis
NDC-.5-0	21.5	0.0	4065.6	882.1	0.0	4005.9	3004.4	3959.5	6.6	974.9	16899.0	Anabaena flos-aquae Anabaena flos-aquae Flagellates
NDC-.5-1	21.1	978.3	401.3	96.2	0.0	3011.0	23.2	255.3	3.3	66.3	4834.9	Flagellates
NDC-.5-2	21.0	82.9	368.1	87.9	0.0	344.9	59.7	179.1	6.6	64.7	1193.8	Anabaena flos-aquae
NDC-1-0	22.0	0.0	2347.8	79.6	0.0	676.5	994.8	4456.9	0.0	490.8	9046.4	Anabaena flos-aquae
NDC-1-1	21.0	99.5	2885.0	179.1	0.0	3137.1	73.0	152.5	3.3	46.4	6575.9	Anabaena flos-aquae Flagellates
NDC-1-2	19.7	23.2	96.2	81.2	0.0	875.5	89.5	155.9	0.0	49.7	1371.2	Flagellates

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
11 JULY 1979 continued.												
NDC-2-0	19.8	331.6	1538.7	66.3	39.8	3760.5	829.0	1200.4	13.3	192.3	7972.0	Flagellates
NDC-2-1	20.5	82.9	1086.0	82.9	5.0	656.6	177.4	179.1	5.0	19.9	2294.8	Anabaena flos-aquae
NDC-2-3	19.5	116.1	384.7	64.7	8.3	1316.5	107.8	136.0	3.3	31.5	2168.7	Flagellates
NDC-4-0	20.0	397.9	212.2	86.2	19.9	5630.8	782.6	1227.0	0.0	218.9	8575.5	Flagellates
NDC-4-1	20.5	1658.1	2339.5	94.5	3.3	341.6	116.1	165.8	1.7	13.3	4733.8	Anabaena flos-aquae
NDC-4-3	19.6	0.0	174.1	14.9	0.0	830.7	137.6	58.0	0.0	19.9	1235.3	Flagellates
NDC-4-4	24.0	19.9	170.8	16.6	0.0	1220.3	175.8	0.0	1.7	5.0	1610.0	Flagellates
NDC-7-1	23.0	0.0	2241.7	96.2	3.3	1833.8	169.1	43.1	0.0	39.8	4427.0	Anabaena flos-aquae
NDC-7-3	23.1	0.0	1207.1	91.2	0.0	515.7	164.1	131.0	0.0	21.6	2130.6	Anabaena flos-aquae
NDC-7-5	24.0	132.6	228.8	154.2	0.0	691.4	152.5	51.4	1.7	31.5	1444.2	Flagellates
SDC-.5-0	21.8	2016.2	1989.7	411.2	0.0	2838.6	5531.3	7839.3	13.3	371.4	21011.0	Flagellates
SDC-.5-1	22.3	114.4	268.6	61.3	21.6	343.2	111.1	374.7	6.6	13.3	1314.8	Anabaena flos-aquae Flagellates Fragilaria crotonensis
SDC-.5-2	21.0	132.6	509.0	38.1	0.0	742.8	121.0	681.5	3.3	74.6	2303.0	Anabaena flos-aquae Flagellates Fragilaria crotonensis
SDC-1-0	22.1	0.0	623.4	159.2	0.0	5040.5	2042.7	3992.6	13.3	490.8	12362.5	Flagellates
SDC-1-1	20.9	0.0	1576.8	24.9	0.0	762.7	81.2	41.5	1.7	28.2	2516.9	Anabaena flos-aquae
SDC-1-2	21.0	0.0	422.8	58.0	3.3	362.3	48.1	19.1	0.8	19.1	933.5	Anabaena flos-aquae
SDC-2-0	21.1	0.0	0.0	424.5	13.3	2109.1	1923.4	2878.4	13.3	676.5	8038.3	Flagellates
SDC-2-1	21.3	0.0	327.5	118.6	1.7	446.8	62.2	80.4	0.8	4.1	1042.1	Anabaena flos-aquae Flagellates
SDC-2-3	20.9	0.0	356.5	107.8	11.6	638.4	97.8	63.0	1.7	26.5	1303.2	Anabaena flos-aquae Flagellates
SDC-4-0	21.2	0.0	4098.7	351.5	0.0	2712.6	656.6	1989.7	19.9	218.9	10047.9	Flagellates
SDC-4-1	21.0	140.9	172.4	44.8	0.0	902.0	92.9	84.6	1.7	13.3	1452.5	Flagellates
SDC-4-3	21.2	0.0	931.8	31.5	0.0	580.3	82.9	23.2	1.7	29.8	1681.3	Anabaena flos-aquae
SDC-4-4	22.0	281.9	878.8	150.9	0.0	918.6	147.6	374.7	0.0	31.5	2783.9	Anabaena flos-aquae
SDC-7-1	21.4	0.0	27.4	31.5	0.0	382.2	42.3	33.2	0.8	13.3	530.6	Flagellates
SDC-7-3	21.0	0.0	493.3	32.3	0.0	463.4	46.4	21.6	0.0	5.0	1062.0	Anabaena flos-aquae
SDC-7-5	22.0	232.1	601.9	91.2	0.0	669.9	102.8	139.3	0.0	43.1	1880.2	Anabaena flos-aquae
18 OCTOBER 1979												
DC-0	13.0	13.3	13.3	318.3	165.8	384.7	4019.1	716.3	0.0	490.8	6121.6	Melosira granulata

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
18 OCTOBER 1979 continued.												
DC-1	17.4	66.3	0.0	82.9	0.0	716.3	749.4	935.1	0.0	39.8	2589.9	Flagellates
DC-2	15.9	1270.1	0.0	218.9	0.0	474.2	295.1	328.3	0.0	205.6	2792.2	Fragilaria crotonensis Anacystis incerta
DC-3	15.6	1101.0	0.0	29.8	0.0	848.9	487.5	232.1	0.0	82.9	2782.2	Gomphosphaeria lacustris
DC-4	15.0	819.1	96.2	19.9	0.0	845.6	175.8	232.1	0.0	66.3	2255.0	Anacystis incerta
DC-5	15.3	1348.0	52.2	50.6	0.0	190.7	102.0	20.7	0.0	14.9	1779.1	Flagellates Anacystis incerta
DC-6	15.0	1295.8	79.6	77.9	0.0	494.1	73.0	5.8	0.0	27.4	2053.5	Anacystis incerta
NDC-.5-0	13.3	0.0	165.8	311.7	13.3	543.8	1704.5	510.7	0.0	689.8	3939.6	Melosira granulata
NDC-.5-1	14.1	3518.4	92.9	109.4	0.0	785.9	550.5	507.4	0.0	49.7	5614.2	Stephanodiscus tenuis Anacystis incerta
NDC-.5-2	13.8	17.4	0.0	53.9	0.0	268.6	141.8	126.0	0.0	29.0	636.7	Flagellates
NDC-1-0	13.1	2845.2	0.0	311.7	106.1	961.7	4616.0	1047.9	0.0	397.9	10286.6	Rhodomonas minuta Anacystis incerta
NDC-1-1	14.1	2240.0	28.2	56.4	0.0	472.5	273.6	197.3	0.0	74.6	3342.7	Melosira granulata Anacystis incerta
NDC-1-2	14.8	1905.1	31.5	39.8	0.0	522.3	278.6	192.3	0.0	91.2	3060.8	Anacystis incerta
NDC-2-0	13.0	0.0	0.0	351.5	26.5	338.2	2500.4	318.3	0.0	218.9	3753.9	Stephanodiscus tenuis
NDC-2-1	14.2	868.8	9.1	32.3	0.0	232.1	50.6	30.7	0.0	18.2	1241.9	Anacystis incerta
NDC-2-3	14.8	755.2	59.7	45.6	0.0	483.3	107.8	29.8	0.0	24.9	1506.4	Anacystis incerta
NDC-4-0	13.9	1777.4	59.7	218.9	13.3	683.1	4317.6	915.3	6.6	848.9	8840.8	Melosira granulata
NDC-4-1	13.9	2339.5	76.3	71.3	0.0	532.2	159.2	69.6	1.7	51.4	3301.2	Anacystis incerta
NDC-4-3	14.8	1249.4	57.2	41.5	0.0	293.5	74.6	21.6	0.0	16.6	1754.2	Anacystis incerta
NDC-4-4	15.0	1687.1	19.1	33.2	0.0	245.4	71.3	12.4	0.0	9.9	2078.4	Anacystis incerta
NDC-7-1	14.5	1522.1	9.9	58.0	0.0	414.5	121.0	266.9	0.0	51.4	2444.0	Anacystis incerta
NDC-7-3	14.7	474.2	89.5	140.9	0.0	422.8	142.6	16.6	0.0	34.8	1321.5	Gomphosphaeria lacustris
NDC-7-5	15.0	1058.7	54.7	47.3	0.0	291.0	74.6	16.6	0.0	19.1	1561.9	Anacystis incerta
SDC-.5-0	13.0	112.7	331.6	245.4	73.0	305.1	3475.3	623.4	0.0	437.7	5604.3	Melosira granulata
SDC-.5-1	14.0	500.7	0.0	59.7	3.3	676.5	308.4	497.4	0.0	66.3	2112.4	Anacystis incerta
SDC-.5-2	14.2	1726.0	1.7	129.3	6.6	674.8	218.9	266.9	0.0	136.0	3160.3	Gomphosphaeria lacustris
SDC-1-0	14.0	1319.8	99.5	344.9	33.2	563.7	3355.9	835.7	0.0	311.7	6864.4	Anacystis incerta Melosira granulata
SDC-1-1	14.0	9016.6	69.6	165.8	0.0	1651.4	381.4	776.0	0.0	175.8	12236.5	Anacystis incerta
SDC-1-2	14.5	2072.6	36.5	102.8	0.0	812.5	333.3	391.3	1.7	124.4	3874.9	Anacystis incerta
SDC-2-0	14.3	444.4	73.0	596.9	19.9	663.2	2487.1	550.5	0.0	497.4	5332.3	Melosira granulata

TABLE 2 continued.

Station	Temperature	Coccoid blue-greens	Filamentous blue-greens	Coccoid greens	Filamentous greens	Flagellates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae	Dominant species
18 OCTOBER 1979 continued.												
SDC-2-1	14.2	1139.1	0.0	86.2	0.0	557.1	457.6	562.1	6.6	149.2	2958.0	Anacystis incerta
SDC-2-3	14.3	2376.8	29.8	36.5	0.0	648.3	112.7	97.0	0.0	97.0	3398.2	Anacystis incerta
SDC-4-0	14.3	182.4	41.5	106.1	8.3	84.6	787.6	271.9	0.0	134.3	1616.6	Melosira granulata
SDC-4-1	14.2	1353.0	9.1	63.8	0.0	570.4	157.5	404.6	0.8	44.8	2604.0	Anacystis incerta
SDC-4-3	14.9	1811.8	19.9	48.9	0.0	175.8	39.8	7.9	0.0	87.5	2191.5	Anacystis incerta
SDC-4-4	14.9	1508.0	100.7	14.9	0.0	362.3	59.7	24.0	0.0	53.1	2122.7	Anacystis incerta
SDC-7-1	14.2	4082.2	69.6	185.7	0.0	829.0	271.9	872.1	0.0	102.8	6413.4	Anacystis incerta
SDC-7-3	14.3	4369.0	77.9	59.7	0.0	469.2	298.5	197.3	0.0	66.3	5537.9	Anacystis incerta
SDC-7-5	14.8	2944.7	56.4	87.9	0.0	331.6	180.7	157.5	0.0	54.7	3813.5	Anacystis incerta

TABLE 3. The dominant and codominant phytoplankters in the Cook Plant seasonal surveys of preoperational 1970 through 1974 and operational 1975 through 1979.

Survey	Species or group	Dominant or codominant occurrences
10 July 1970	Tabellaria fenestrata (diatom)	40
	Cyclotella sp. (diatom)	9
	Fragilaria crotonensis (diatom)	7
	Melosira sp. (diatom)	3
	Dinobryon divergens (flagellate)	2
	Flagellates	2
	Melosira granulata (diatom)	2
	Melosira granulata v. angustissima (diatom)	2
	Oocystis solitaria (green)	2
	Anabaena circinalis (blue-green)	1
	Chlamydomonas sp. (flagellate)	1
	Microcystis aeruginosa (blue-green)	1
	Melosira islandica (diatom)	1
	Melosira italica (diatom)	1
25 Sept 1970	Chlamydomonas sp. (flagellate)	28
	Fragilaria crotonensis (diatom)	13
	Dinobryon divergens (flagellate)	10
	Oocystis sp. (green)	10
	Gloeocystis sp. (green)	7
	Melosira granulata (diatom)	7
	Chroococcus limneticus (blue-green)	4
	Ochromonas sp. (flagellate)	3
	Melosira granulata v. angustissima (diatom)	2
	Peridinium sp. (flagellate)	2
	Closteriopsis sp. ("other" alga*)	1
	Cryptomonas sp. (flagellate)	1
	Cyclotella sp. (diatom)	1
	Tabellaria fenestrata (diatom)	1
	Tetraedron minimum ("other" alga*)	1
12 Nov 1970	Ochromonas sp. (flagellate)	33
	Chlamydomonas sp. (flagellate)	19
	Cryptomonas sp. (flagellate)	3
	Fragilaria crotonensis (diatom)	3
	Crucigenia rectangularis ("other" alga*)	1
	Cyclotella sp. (diatom)	1

(continued)

TABLE 3. Continued.

Survey	Species or group	Dominant or codominant occurrences
15 April 1971	Ochromonas sp. (flagellate)	24
	Melosira sp. (diatom)	15
	Chlamydomonas sp. (flagellate)	15
	Tabellaria fenestrata (diatom)	14
	Stephanodiscus sp. (diatom)	13
	Fragilaria crotonensis (diatom)	9
	Cyclotella sp. (diatom)	6
	Fragilaria sp. (diatom)	1
9 July 1971	Gloeocystis sp. (green)	47
	Oocystis sp. (green)	18
	Glenodinium sp. (flagellate)	12
	Dinobryon divergens (flagellate)	10
	Tabellaria fenestrata (diatom)	8
	Cyclotella sp. (diatom)	4
	Fragilaria crotonensis (diatom)	3
	Scenedesmus sp. ("other" alga*)	1
	Crucigenia sp. ("other" alga*)	1
	Fragilaria sp. (diatom)	1
	Westella linearis (green)	1
8 Nov 1971	Ochromonas sp. (flagellate)	20
	Tabellaria fenestrata (diatom)	17
	Fragilaria crotonensis (diatom)	7
	Gloeocystis sp. (green)	6
	Chlamydomonas sp. (flagellate)	4
	Cryptomonas sp. (flagellate)	3
	Aphanothece sp. (blue-green)	2
	Oocystis sp. (green)	1
	Fragilaria sp. (diatom)	1
12 April 1972	Tabellaria fenestrata (diatom)	13
	Chlamydomonas sp. (flagellate)	8
	Cyclotella sp. (diatom)	7
	Stephanodiscus sp. (diatom)	6
	Gloeocystis sp. (green)	4

(continued)

TABLE 3. Continued.

Survey	Species or group	Dominant or codominant occurrences
16 July 1972	Tabellaria fenestrata (diatom)	14
	Gloeocystis sp. (green)	5
	Chlamydomonas sp. (flagellate)	5
	Fragilaria intermedia (diatom)	4
	Fragilaria capucina (diatom)	4
	Fragilaria crotonensis (diatom)	3
	Dinobryon sp. (flagellate)	3
	Flagellates	2
	Anabaena sp. (blue-green)	2
	Glenodinium sp. (flagellate)	1
	Oocystis sp. (green)	1
15 Oct 1972	Melosira granulata (diatom)	26
	Chroococcus limneticus (blue-green)	4
	Flagellates	3
	Chroococcussp. (blue-green)	2
25 April 1973	Stephanodiscus minutus (diatom)	21
	Flagellates	12
	Cyclotella sp. (diatom)	5
	Stephanodiscus sp. (diatom)	3
	Fragilaria crotonensis (diatom)	1
	Gloeocystis sp. (green)	1
	Chlamydomonassp. (flagellate)	1
	Melosira granulata (diatom)	1
	Tabellaria fenestrata v. intermedia (diatom)	1
19 July 1973	Stephanodiscus tenuis (diatom)	19
	Cyclotella stelligera (diatom)	10
	Melosira granulata v. angustissima (diatom)	4
	Chlamydomonas sp. (flagellate)	4
	Cyclotella sp. (diatom)	2
	Cyclotella atomus (diatom)	1
	Anacystis incerta (blue-green)	1
	Flagellates	1
	Gloeocystis sp. (green)	1
	Coccomyxa coccoides (green)	1
23 Oct 1973	Melosira granulata v. angustissima (diatom)	20
	Flagellates	9
	Chlamydomonas sp. (flagellate)	3
	Fragilaria crotonensis (diatom)	2
	Melosira granulata (diatom)	1

(continued)

TABLE 3. Continued.

Survey	Species or group	Dominant or codominant occurrences
20 April 1974	Fragilaria crotonensis (diatom)	20
	Flagellates	18
	Stephanodiscus tenuis (diatom)	11
	Synedra filiformis (diatom)	3
	Fragilaria intermedia v. fallax (diatom)	1
	Melosira granulata (diatom)	1
	Melosira italica (diatom)	1
	Stephanodiscus minutus (diatom)	1
11 July 1974	Fragilaria crotonensis (diatom)	27
	Flagellates	21
	Anacystis incerta (blue-green)	2
	Anabaena flos-aquae (blue-green)	1
	Cyclotella stelligera (diatom)	1
	Tabellaria fenestrata v. intermedia (diatom)	1
	Thalassiosira pseudonana (diatom)	1
	Stephanodiscus tenuis (diatom)	1
9 Oct 1974	Anacystis incerta (blue-green)	22
	Flagellates	21
	Gomphosphaeria lacustris (blue-green)	11
	Anacystis thermalis (blue-green)	3
	Fragilaria crotonensis (diatom)	2
	Asterionella formosa (doatom)	1
	Melosira granulata (diatom)	1
	Stephanodiscus minutus (diatom)	1
	Stephanodiscus tenuis (diatom)	1
17 April 1975	Flagellates	24
	Stephanodiscus tenuis (diatom)	17
	Fragilaria crotonensis (diatom)	15
	Stephanodiscus minutus (diatom)	8
	Cyclotella stelligera (diatom)	7
	Tabellaria flocculosa (diatom)	3
	Tabellaria fenestrata v. intermedia (diatom)	1
	Melosira islandica (diatom)	1
	Anacystis incerta (blue-green)	1
	Fragilaria capucina (diatom)	1
	Fragilaria intermedia (diatom)	1
	Synedra filiformis (diatom)	1

(continued)

TABLE 3. Continued.

Survey	Species or group	Dominant or codominant occurrences
17 July 1975	Gloeocystis sp. (green)	20
	Flagellates	15
	Anabaena flos-aquae (blue-green)	10
	Green coccoid unknown	4
	Fragilaria crotonensis (diatom)	1
	Cyclotella stelligera (diatom)	1
	Gloeocystis planctonica (green)	1
17 Oct 1975	Anacystis incerta (blue-green)	22
	Gomphosphaeria lacustris (blue-green)	15
	Fragilaria crotonensis (diatom)	9
	Flagellates	5
	Anabaena flos-aquae (blue-green)	1
	Gloeocystis sp. (green)	1
	Ochromonas sp. (flagellate)	1
	Synedra filiformis (diatom)	1
14 April 1976	Flagellates	23
	Fragilaria crotonensis (diatom)	18
	Asterionella formosa (diatom)	16
	Stephanodiscus sp. (diatom)	8
	Anacystis incerta (blue-green)	4
	Stephanodiscus subtilis (diatom)	4
	Rhizosolenia gracilis (diatom)	2
	Stephanodiscus minutus (diatom)	2
	Gomphosphaeria lacustris (blue-green)	1
	Ulothrix sp. (green)	1
14 July 1976	Flagellates	24
	Gloeocystis sp. (green)	12
	Anabaena flos-aquae (blue-green)	9
	Gomphosphaeria lacustris (blue-green)	4
	Anacystis incerta (blue-green)	2
	Cyclotella stelligera (diatom)	2
	Fragilaria crotonensis (diatom)	2
	Gloeocystis planctonica (green)	1
	Oocystis sp. (green)	1
	Pediastrum duplex ("other" alga*)	1

(continued)

TABLE 3. Continued.

Survey	Species or group	Dominant or codominant occurrences
14 Oct 1976	Flagellates	28
	Fragilaria crotonensis (diatom)	11
	Gomphosphaeria lacustris (blue-green)	8
	Anacystis incerta (blue-green)	6
	Cyclotella comensis (diatom)	5
	Gloeocystis sp. (green)	5
	Anabaena flos-aquae (blue-green)	1
	Gloeocystis planctonica (green)	1
	Melosira granulata (diatom)	1
14 April 1977	Flagellates	24
	Ochromonas sp. (flagellate)	19
	Fragilaria crotonensis (diatom)	13
	Synedra ostenfeldii (diatom)	5
	Synedra filiformis (diatom)	2
	Anacystis incerta (blue-green)	1
	Cyclotella stelligera (diatom)	1
13 July 1977	Fragilaria crotonensis (diatom)	15
	Cyclotella comensis (diatom)	15
	Anabaena flos-aquae (blue-green)	11
	Flagellates	6
	Cyclotella sp. (diatom)	5
	Anacystis incerta (blue-green)	3
	Cyclotella michiganiana (diatom)	3
14 Oct 1977	Anacystis incerta (blue-green)	24
	Gomphosphaereia lacustris (blue-green)	12
	Flagellates	10
	Fragilaria crotonensis (diatom)	6
	Melosira granulata (diatom)	2
	Agmenellum quadruplicatum (blue-green)	1
14 April 1978	Flagellates	34
	Ochromonas sp. (flagellate)	11
	Stephanodiscus sp. #5 (diatom)	6
	Stephanodiscus sp. (diatom)	5
	Fragilaria crotonensis (diatom)	4
	Asterionella formosa (diatom)	3
	Unknown coccoid green	3
	Anacystis incerta (blue-green)	2

(continued)

TABLE 3. Concluded.

Survey	Species or group	Dominant or codominant occurrences
12 July 1978	Flagellates	31
	Fragilaria crotonensis (diatom)	13
	Melosira granulata (diatom)	8
	Anacystis incerta (blue-green)	8
	Tabellaria fenestrata v. intermedia (diatom)	6
	Anabaena flos-aquae (blue-green)	2
	Anacystis cyanea (blue-green)	1
	Stephanodiscus sp. (diatom)	1
11 Oct 1978	Anacystis incerta (blue-green)	37
	Gomphosphaeria lacustris (blue-green)	7
	Melosira granulata (diatom)	3
	Flagellates	1
	Rhodomonas minuta (flagellate)	1
12 April 1979	Stephanodiscus hantzschii (diatom)	24
	Asterionella formosa (diatom)	19
	Stephanodiscus sp. (diatom)	11
	Flagellates	4
	Ochromonas sp. (flagellate)	3
	Gomphosphaeria lacustris (blue-green)	1
	Anacystis incerta (blue-green)	1
	Stephanodiscus alpinus (diatom)	1
11 July 1979	Anabaena flos-aquae (blue-green)	25
	Flagellates	20
	Fragilaria crotonensis (diatom)	3
18 Oct 1979	Anacystis incerta (blue-green)	27
	Melosira granulata (diatom)	8
	Flagellates	3
	Gomphosphaeria lacustris (blue-green)	3
	Stephanodiscus tenuis (diatom)	2
	Fragilaria crotonensis (diatom)	1
	Rhodomonas minuta (flagellate)	1

*A green alga, but coded as "other" because it is neither filamentous nor coccoid.

their dominant or codominant occurrences given. This is done to assist the reader in sorting the probably important dominants and codominants from the rare ones which might be due to the chance capture of a single many-celled filament or colony.

Beginning in 1972 there has been a trend toward increasing numbers of cases of dominance or codominance by blue-green algae. Heavy dominance by the blue-greens Anacystis incerta and Gomphosphaeria lacustris first appeared in October 1974 and has been characteristic of Octobers in subsequent years; moderate to heavy dominance by Anabaena flos-aquae began in July of 1975 and has been typical of Julys in following years. These dominances are consistent with the findings by Tarapchak and Stoermer (1976) and others that in recent years blue-greens have increased in Lake Michigan as a result of summer and fall depletion of silica in the epilimnion; being lake-caused, the more frequent dominances by blue-greens cannot be attributed to Cook Plant operation.

Master Lists of Phytoplankters Collected

Appendix C presents the lists of phytoplankters collected in the seasonal surveys of 1978 and 1979. Ayers and Wiley (1979) list the collections of 1977. Ayers (1978) lists the collections of 1976 and previously unreported September 1970. Ayers, Southwick, and Robinson (1977) give the master lists for the surveys of 1974 and 1975. Ayers (1975) presents the lists for the surveys of 1972 and 1973. Ayers, Mozley, and Stewart (1974) list the species collected in the seasonal surveys of 1971. Ayers, Mozley, and Roth (1973) give the master list for November 1970. Ayers et al. (1971) list the species taken in the July survey of 1970.

Apparent Establishment of Cyclotella comensis

The centric diatom, Cyclotella comensis, previously not found in Cook Plant area phytoplankton samples, first occurred in the collections of October 1975 and has been taken in each seasonal survey since then. Typically present in low abundances, this diatom attained to dominant or codominant status in five stations of the October 1976 survey and in 15 stations of the July 1977 survey. It was present in 74% to 100% of the station samples in the surveys of 1978 and 1979; in these 2 years its greatest abundances were in October 1979 at station DC-1 (9.86% of the population) and at station SDC-2-1 (5.56%). Apparently this diatom has become established at low abundance levels in the Cook Plant sampling area.

Inner-Outer Graphical Comparisons: Diversity Indices

Cook Plant species diversity data for the years 1971 through 1977 have been presented by Ayers, Southwick, and Robinson (1977), Ayers (1978), and Ayers and Wiley (1979); this section extends those reports to include the seasonal surveys of 1978 and 1979.

As was done previously, the diversity index data have been stratified by three depth zones and by inner treatment stations (near the plant) and outer control or reference stations groups. The diversity index used is, as previously, that of Wilhm and Dorris (1968):

$$\bar{d} = - \sum_{i=1}^{S} (n_i/n) \log_2 (n_i/n)$$

where S is the number of species, n is the total number of phytoplankton in cells/mL, n_i is the number of phytoplankton of the i^{th} species.

Mean diversity indices and associated standard errors for each depth-zone-station-group combination in 1978-79 have been computed and are presented in Table 4. In Figure 2 the surveys of 1978-79 have been added at the end of the time plots of diversity indices and standard errors which were presented by Ayers and Wiley (1979).

In Figure 2 the annual curves of mean diversity indices generally show substantial degrees of parallelism between inner (treatment) and outer (control) station groups. Parallelism between the curve for inner and outer stations indicates that changes in diversity from season to season have been the same in both sets of stations. Parallelism of the curves in the operational years 1975 through 1979 has been as good as or better than in the preoperational years.

The placement, on the graphs, of annual curves for inner and outer station groups indicates that in zones 0 and 1 the diversities for 1979 were lower than in the preceding operational years; in zone 2 the diversities were not noticeably different from those of preceding years. In all zones diversities were higher than in preoperational years prior to 1974.

Inner-Outer Graphical Comparisons: Phytoplankton Redundancies

Redundancy values are derived from the diversity index of Wilhm and Dorris (1968):

$$\bar{d} = - \sum_{i=1}^{S} (n_i/n) \log_2 (n_i/n)$$

where S is the number of species, n is the total number of phytoplankton in cells/mL, n_i is the number of phytoplankton of the i^{th} species. Diversity as presented here is not the true diversity since not all forms encountered can be identified to the species level. Therefore, this diversity must be viewed with

TABLE 4. Means, standard errors, and numbers of observations of phytoplankton diversities by seasons, depth zones, and inner or outer station groups in Cook Plant major surveys during operational 1978 and 1979. Standard errors are computed only when the number of observations is two or more.

	1978			1979		
	14 April	12 July	11 October	12 April	11 July	18 October
Zone 0 Inner						
Mean	4.47	4.60	3.77	4.10	3.43	3.79
S. E.	0.10	0.17	0.17	0.06	0.27	0.18
N	12	12	12	12	12	12
Outer						
Mean	4.61	4.66	4.01	4.13	2.96	3.58
S. E.	0.11	0.10	0.16	0.08	0.21	0.23
N	10	10	10	10	10	10
Zone 1 Inner						
Mean	4.22	4.14	3.21	3.95	2.94	3.43
S. E.	0.14	0.13	0.27	0.13	0.33	0.36
N	3	3	3	3	3	3
Outer						
Mean	3.98	4.51	3.29	4.07	2.74	3.03
S. E.	0.12	0.10	0.27	0.05	0.29	0.29
N	4	4	4	4	4	4
Zone 2 Inner						
Mean	4.02	4.36	3.60	4.08	2.77	4.09
S. E.	0.15	0.16	0.58	0.21	0.44	0.13
N 2	2	2	2	2	2	2
Outer						
Mean	4.07	3.95	2.74	4.14	2.82	2.56
S. E.	0.17	0.51	0.49	0.11	0.30	0.22
N	4	4	4	4	4	4

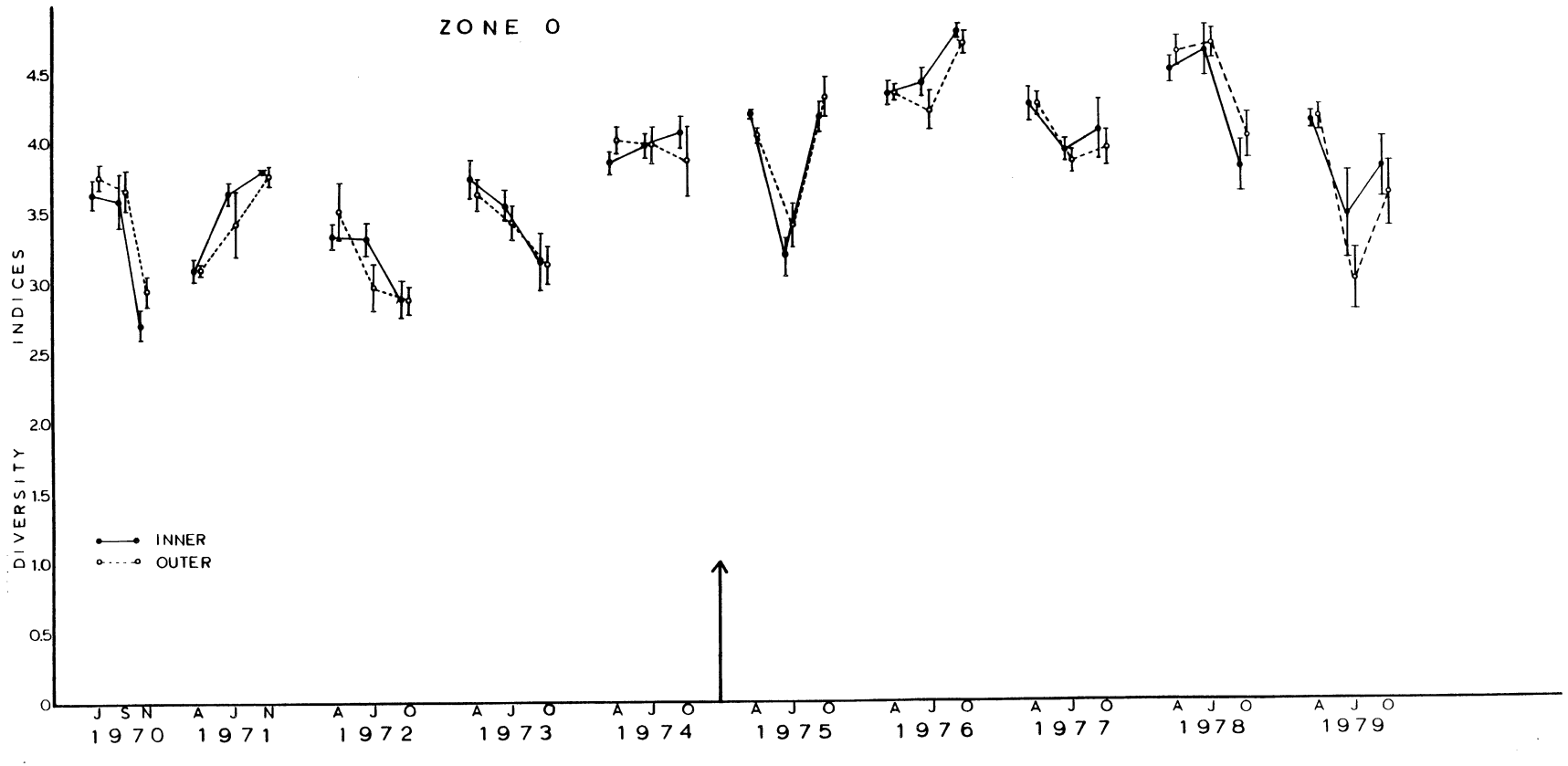

FIG. 2A. Mean diversity indices in zone 0 by spring, summer, and fall seasons and inner and outer station groups in 1970 through 1979. The vertical bars show the standard errors. See Table 4 for numbers of observations.

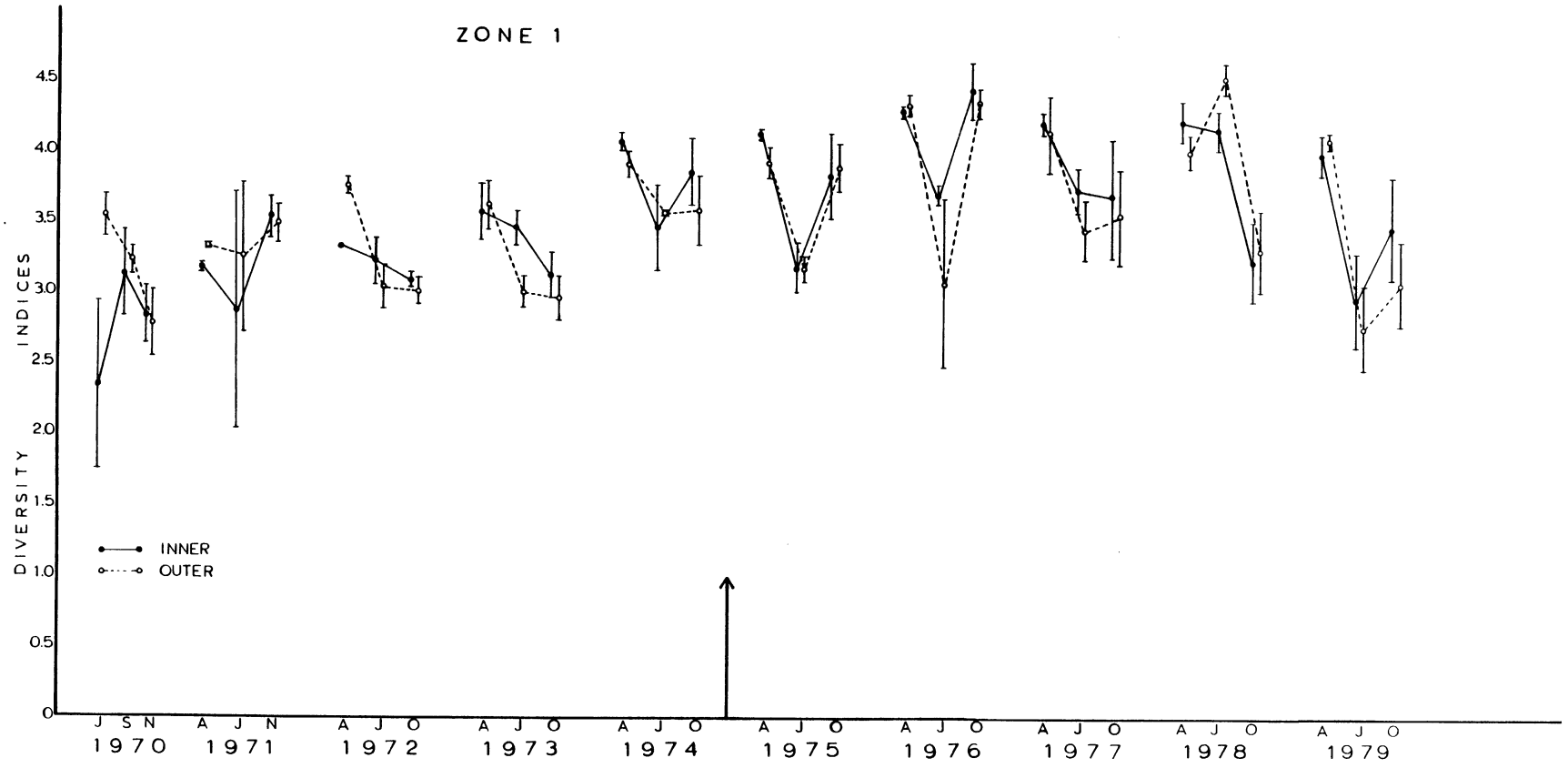

FIG. 2B. Mean diversity indices in zone 1 by spring, summer, and fall seasons and inner and outer station groups in 1970 through 1979. The vertical bars show the standard errors. See Table 4 for numbers of observations.

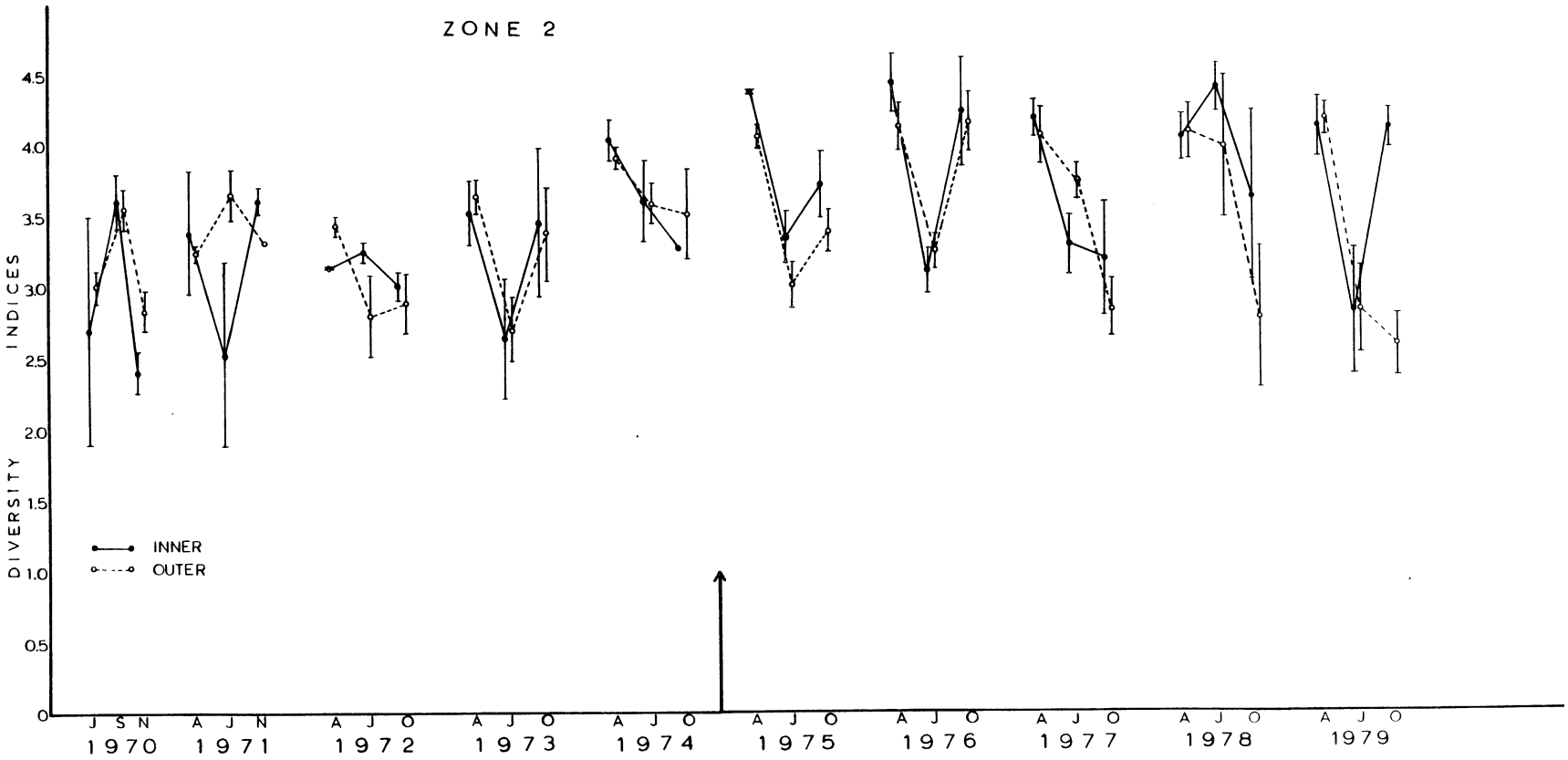

FIG. 2C. Mean diversity indices in zone 2 by spring, summer, and fall seasons and inner and outer station groups in 1970 through 1979. The vertical bars show the standard errors. See Table 4 for numbers of observations.

caution. However, since these diversities do mean something about community structure they will be used to illustrate changes occurring within the phytoplankton population from year to year and for the derivation of redundancies.

Redundancy is a measure of the dominance of one or a few species within a given population. As presented by Wilhm and Dorris (1968) it is:

$$r = \frac{\bar{d}_{max} - \bar{d}}{\bar{d}_{max} - \bar{d}_{min}}$$

where $\bar{d}$ is the observed diversity as calculated above, $\bar{d}_{max}$ is the maximum diversity for a particular community, and $\bar{d}_{min}$ is the minimum possible diversity for a particular community. $\bar{d}_{max}$ is calculated using the following equation:

$$\bar{d}_{max} = (1/n)(\log_2 n! - s \log_2 [n/S]!)$$

and $\bar{d}_{min}$ is calculated using the equation:

$$\bar{d}_{min} = (1/n)(\log_2 n! - s \log_2 [n-(S-1)]!)$$

The values of r range between 0 and 1. An r equal to 0 implies that the species encountered in a community each have the same number of cells. An r equal to 1 implies that one species dominates the community of phytoplankton. As redundancy values are not given in Appendix B, it is necessary to give them here (Table 5). The values for years 1970 - 1976 have been reported by Ayers (1978); those for 1977 were reported by Ayers and Wiley (1979). Table 5 gives the means, standard errors, and numbers of observations of redundancies in Cook

TABLE 5. Means, standard errors, and numbers of observations of phytoplankton redundancies by seasons, depth zones, and inner or outer station groups in Cook Plant major surveys during operational 1978 and 1979. Standard errors are computed only when the number of observations is two or more.

	1978			1979		
	14 April	12 July	11 October	12 April	11 July	18 October
Zone 0 Inner						
Mean	0.260	0.277	0.408	0.310	0.380	0.351
S. E.	0.010	0.013	0.014	0.011	0.038	0.028
N	12	12	12	12	12	12
Outer						
Mean	0.250	0.273	0.359	0.319	0.457	0.390
S. E.	0.020	0.010	0.027	0.012	0.028	0.031
N	10	10	10	10	10	10
Zone 1 Inner						
Mean	0.280	0.295	0.455	0.326	0.458	0.417
S. E.	0.030	0.026	0.067	0.034	0.060	0.065
N	3	3	3	3	3	3
Outer						
Mean	0.300	0.245	0.447	0.299	0.443	0.451
S. E.	0.020	0.010	0.051	0.010	0.035	0.061
N	4	4	4	4	4	4
Zone 2 Inner						
Mean	0.300	0.280	0.328	0.267	0.484	0.258
S. E.	0.010	0.015	0.082	0.032	0.065	0.020
N	2	2	2	2	2	2
Outer						
Mean	0.280	0.336	0.328	0.291	0.434	0.543
S. E.	0.030	0.076	0.082	0.005	0.060	0.040
N	4	4	4	4	4	4

Plant seasonal surveys during 1978 and 1979 stratified by seasons, depth zones, and inner and outer station groups. The means and standard errors are plotted on a time axis in Figure 3.

The plots in Figure 3 show visual evidence of a trend, beginning in 1973, for redundancies to have become somewhat lower since that year. If real, the trend would indicate that there has been a tendency for the species in the community to have become more nearly equally abundant in numbers of individuals.

Perhaps more important is that after 1972 there has been much better parallelism between the annual curves of redundancies at inner and outer station groups; that is, changes in mean redundancies of collections from the two station groups have been much more alike than was the case in earlier preoperational years. As it began in the preoperational years and has continued into the operational years, the tendency for improved parallelism is attributed to some cause in the lake itself.

There is nothing in this analysis of phytoplankton redundancies to indicate that the operation of Cook Plant has exerted any adverse impact on the local phytoplankton community.

Inner-Outer Graphical Comparisons: Phytoplankton Abundances By Algal Categories

This section applies the inner-outer graphical analysis method to the abundances (in cells per mL) of ten major categories of phytoplankton and extends previously reported tabulations, figures, and discussions to include the seasonal surveys of 1978 and 1979. Earlier years were reported by Ayers, Southwick, and Robinson (1977); 1977 was reported by Ayers and Wiley (1979).

The phytoplankton abundances used are those of total algae and of the nine major algal groups: coccoid blue-greens, filamentous blue-greens, coccoid

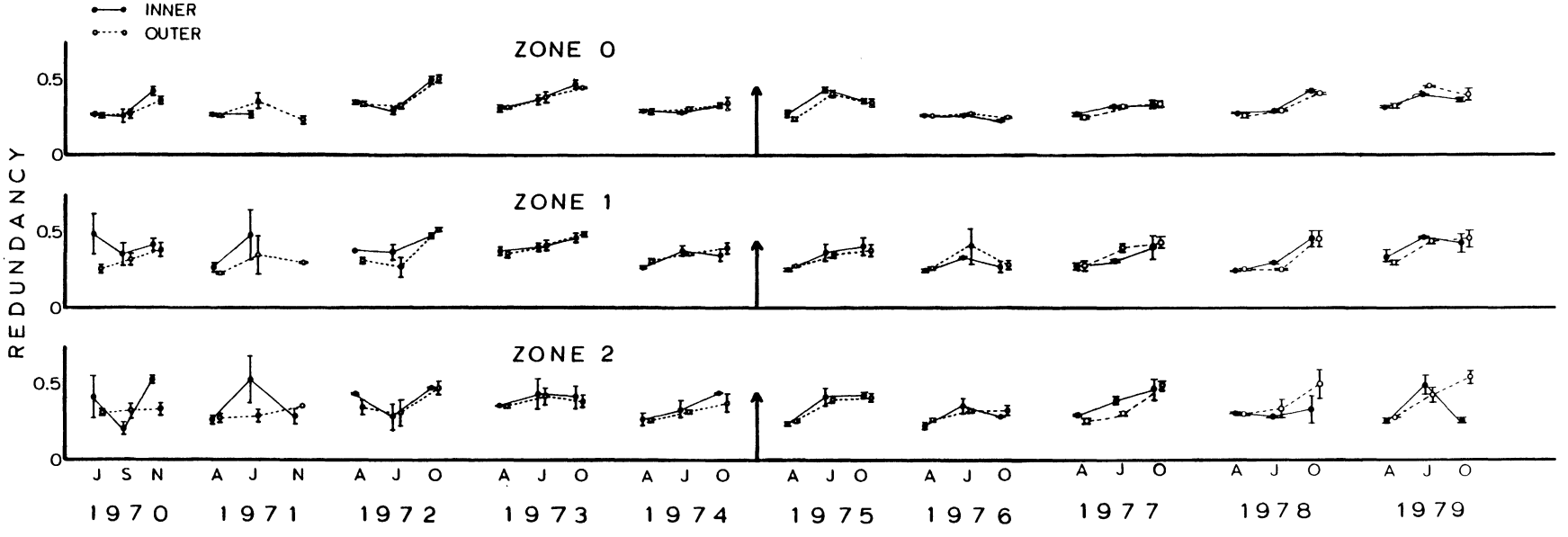

FIG. 3. Mean redundancies of phytoplankton collections from three depth zones in the Cook Plant area, by spring, summer, and fall seasons and inner and outer station groups in 1970 through 1979. The vertical bars show the standard errors. See Table 5 for numbers of observations.

greens, filamentous greens, flagellates, centric diatoms, pennate diatoms, desmids, and other algae. The use of major algal groups bypasses difficulties stemming from inability always to identify to species, and is justifiable on the basis that members of each individual group have more or less similar functions in the ecosystem.

Table 6 presents, for the seasonal surveys of 1978 and 1979, means, standard errors, and numbers of observations of abundances of total algae and the nine major groups of planktonic algae in the three depth zones and the inner and outer station groups. These are graphed with the preceding years in Figure 4.

Desmids (Fig. 4A) have shown almost no variation in abundance over the entire 10 years of the study.

Filamentous green algae (Fig. 4B), which in April 1976 had somewhat increased in abundance in both station groups and in all three depth zones, returned to preoperational levels in July of that year and have remained there ever since.

Other algae (Fig. 4C) increased in abundance in all depth zones and both station groups in 1976 and 1978, but similar abundances had been observed in preoperational years. There is no clear evidence that the recent greater abundances were plant-induced.

Filamentous blue-green algae (Fig. 4D) have been more abundant in all depth zones and both sets of stations in the 5 operational years. In zones 0 and 1 increases at the outer stations equalled or exceeded those at the inner stations in all 5 years. In 1977 and 1979 in zone 2 July abundances at the inner stations greatly exceeded those at the outer stations. Although these inner stations are in front of the plant, they are offshore stations where the plant's

TABLE 6. Means, standard errors, and numbers of observations of phytoplankton abundances by seasons, depth zones, and inner or outer station groups in Cook Plant major surveys during 1978 and 1979. B-G = blue-greens, Filam. = filamentous.

Zone	Inner, Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total
14 April 1978											
0	Inner										
	Mean	55.83	3.58	417.28	3.87	1,180.27	1,273.39	884.31	0.55	50.58	3,869.44
	S. E.	30.88	1.89	143.36	3.87	109.99	142.40	96.56	0.37	9.58	356.68
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	138.62	4.96	317.04	1.66	1,114.23	1,146.39	1,035.30	0.33	53.05	3,811.54
	S. E.	58.69	1.42	171.93	1.33	130.48	100.05	75.30	0.33	12.52	252.96
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	116.07	5.53	123.80	1.10	1,272.83	1,250.20	919.70	1.10	58.57	3,748.87
	S. E.	116.06	4.00	10.89	1.10	371.99	386.87	196.17	1.10	19.68	1,023.72
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	26.53	4.13	114.03	6.65	1,592.58	910.25	692.65	0.83	52.65	3,400.25
	S. E.	24.38	1.58	8.86	3.84	267.37	150.66	186.16	0.83	17.29	316.88
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	0.00	13.25	73.75	0.00	1,243.55	682.30	444.35	0.00	29.00	2,486.30
	S. E.	0.00	9.95	38.95	0.00	338.25	299.30	192.35	0.00	0.80	879.60
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	37.30	4.55	41.88	2.48	1,154.83	636.68	345.28	0.00	36.88	2,259.95
	S. E.	37.30	1.23	12.93	2.48	121.92	50.79	52.25	0.00	3.61	99.73
	N	4	4	4	4	4	4	4	4	4	4

(continued)

TABLE 6. Continued.

Zone	Inner, Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total
12 July 1978											
0	Inner										
	Mean	803.33	196.62	189.85	23.76	1,181.23	3,780.93	4,693.83	8.43	451.69	11,329.69
	S. E.	276.15	92.73	55.33	7.96	162.04	1,192.13	1,371.07	3.11	98.05	2,837.24
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	1,082.37	199.61	238.76	31.83	1,695.11	3,923.30	6,461.81	8.28	608.84	14,253.04
	S. E.	324.97	60.76	90.99	9.25	295.26	1,333.29	2,188.01	4.05	56.68	3,654.73
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	259.77	170.77	43.63	12.13	869.93	579.80	727.33	0.57	271.37	2,935.37
	S. E.	134.14	139.35	29.99	5.85	15.93	71.64	321.09	0.57	50.61	598.50
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	290.58	49.75	173.25	26.53	1,309.88	599.38	682.73	4.55	416.18	3,552.83
	S. E.	40.37	11.24	69.41	9.30	215.78	134.18	182.43	2.65	98.11	576.86
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	248.70	36.45	58.85	9.10	613.50	450.20	646.65	1.65	127.70	2,192.80
	S. E.	99.50	24.85	27.35	9.10	31.50	100.30	159.15	1.65	91.20	77.10
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	21.55	463.00	177.83	19.88	1,448.73	491.60	871.73	3.30	291.40	3,789.10
	S. E.	21.55	424.60	73.33	5.74	337.49	142.50	118.80	1.35	117.01	164.89
	N	4	4	4	4	4	4	4	4	4	4

(continued)

TABLE 6. Continued.

Zone	Inner, Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total
11 October 1978											
0	Inner										
	Mean	3,966.64	170.09	507.49	3.59	774.04	1,471.52	910.13	2.76	419.33	8,227.30
	S. E.	542.74	45.46	121.59	1.66	104.79	409.85	214.33	1.34	98.44	1,228.32
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	2,772.91	106.61	476.53	5.46	786.42	1,107.59	659.25	0.99	291.49	6,205.45
	S. E.	440.35	22.98	109.46	2.10	83.20	198.53	84.98	0.71	63.44	607.25
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	5,002.93	99.47	264.20	4.40	927.43	472.03	497.43	1.10	165.80	7,434.73
	S. E.	2,630.76	73.87	127.36	2.20	234.32	92.15	145.01	1.10	70.06	3,346.95
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	2,180.98	72.10	89.95	4.98	611.20	360.23	282.08	0.20	118.78	3,720.48
	S. E.	868.02	30.60	33.84	4.98	194.25	211.07	72.10	0.20	66.31	1,860.24
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	798.40	74.60	104.50	0.0	473.35	121.00	192.30	0.85	64.65	1,829.70
	S. E.	37.30	51.40	11.60	0.0	150.05	91.20	102.80	0.85	64.65	382.20
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	3,432.20	177.03	42.25	0.43	786.75	149.23	86.63	0.85	72.55	4,747.85
	S. E.	1,538.83	82.02	15.75	0.43	54.70	44.89	8.70	0.49	14.26	1,581.04
	N	4	4	4	4	4	4	4	4	4	4

(continued)

TABLE 6. Continued.

Zone	Inner, Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total
12 April 1979											
0	Inner										
	Mean	14.37	2.48	130.71	11.88	522.30	2,822.10	1,082.71	1.66	63.00	4,651.98
	S. E.	11.00	1.09	34.89	10.69	79.07	345.47	138.13	1.19	13.63	527.25
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	141.28	3.30	136.14	4.48	785.10	3,581.08	1,567.55	1.32	79.42	6,299.64
	S. E.	63.89	1.20	28.52	2.04	132.96	580.65	245.34	0.73	16.18	958.57
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	0.0	0.0	91.77	1.10	636.67	2,627.47	959.47	0.0	77.40	4,393.87
	S. E.	0.0	0.0	32.97	1.10	294.18	724.57	420.15	0.0	30.54	1,478.06
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	165.80	4.13	88.70	9.95	693.08	1,935.05	1,086.03	2.48	72.95	4,058.10
	S. E.	165.80	1.58	20.59	9.95	129.02	549.07	181.13	1.58	22.77	674.37
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	285.20	0.0	72.95	0.0	623.45	1,880.25	686.40	0.0	82.90	3,631.15
	S. E.	285.20	0.0	13.25	0.0	33.15	427.75	63.00	0.0	36.50	96.15
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	56.38	5.80	42.70	0.0	895.35	1,354.65	1,111.33	0.43	48.93	3,515.50
	S. E.	47.95	3.69	12.26	0.0	184.66	371.23	230.50	0.43	17.31	585.98
	N	4	4	4	4	4	4	4	4	4	4

(continued)

TABLE 6. Continued.

Zone	Inner, Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total
11 July 1979											
0	Inner										
	Mean	301.91	1,704.49	245.12	2.08	2,082.67	1,314.43	2,269.62	6.49	305.51	8,232.28
	S. E.	174.41	393.27	86.17	1.80	467.11	531.67	763.51	1.33	102.52	2,029.71
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	261.14	1,204.41	139.70	8.63	1,877.60	1,396.77	788.20	5.65	141.03	4,911.45
	S. E.	162.01	428.45	42.50	4.03	552.47	886.98	317.18	2.27	66.17	1,116.51
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	40.90	442.70	54.13	1.10	623.73	84.57	171.07	0.27	32.33	1,450.80
	S. E.	30.06	206.04	16.85	1.10	148.23	19.79	92.43	0.27	9.07	324.10
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	29.03	610.40	74.00	4.98	733.55	104.03	87.90	1.25	21.15	1,666.13
	S. E.	29.03	201.08	16.49	2.95	197.77	24.12	27.67	0.79	5.75	283.58
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	58.05	1,219.50	81.25	3.30	795.85	112.75	241.25	0.0	62.15	2,574.15
	S. E.	58.05	274.40	38.15	3.30	56.35	8.25	82.05	0.0	38.95	118.55
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	91.18	484.15	72.95	0.0	693.08	118.95	67.98	0.85	31.08	1,560.25
	S. E.	56.42	176.92	31.65	0.0	51.80	15.90	24.95	0.49	4.76	140.26
	N	4	4	4	4	4	4	4	4	4	4

(continued)

TABLE 6. Concluded.

Zone	Inner, Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total
18 October 1979											
0	Inner										
	Mean	1,781.38	66.88	182.45	33.44	667.08	1,649.57	586.68	0.0	241.59	5,209.10
	S. E.	747.22	23.62	33.49	15.57	106.80	494.68	84.22	0.0	63.22	975.87
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	1,370.89	34.82	177.07	6.80	490.44	1,131.05	426.20	1.57	211.73	3,850.61
	S. E.	377.51	10.23	55.87	3.13	71.07	452.57	95.27	0.86	83.41	746.12
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	1,729.27	22.67	120.50	0.0	603.00	302.33	303.97	0.57	140.40	3,242.63
	S. E.	244.42	11.43	52.45	0.0	105.67	16.12	58.72	0.57	33.98	325.50
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	1,993.80	64.23	70.68	0.0	505.90	165.40	85.18	0.0	55.75	2,941.00
	S. E.	895.90	13.01	23.89	0.0	49.20	45.03	41.32	0.0	16.34	984.63
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	960.05	48.10	24.85	0.0	847.25	331.65	232.10	0.0	74.60	2,518.60
	S. E.	140.95	48.10	4.95	0.0	1.65	155.85	0.0	0.0	8.30	263.60
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	1,766.15	47.05	56.40	0.0	272.73	92.41	55.40	0.0	44.48	2,330.28
	S. E.	424.13	9.07	10.62	0.0	33.94	30.55	40.14	0.0	16.78	511.66
	N	4	4	4	4	4	4	4	4	4	4

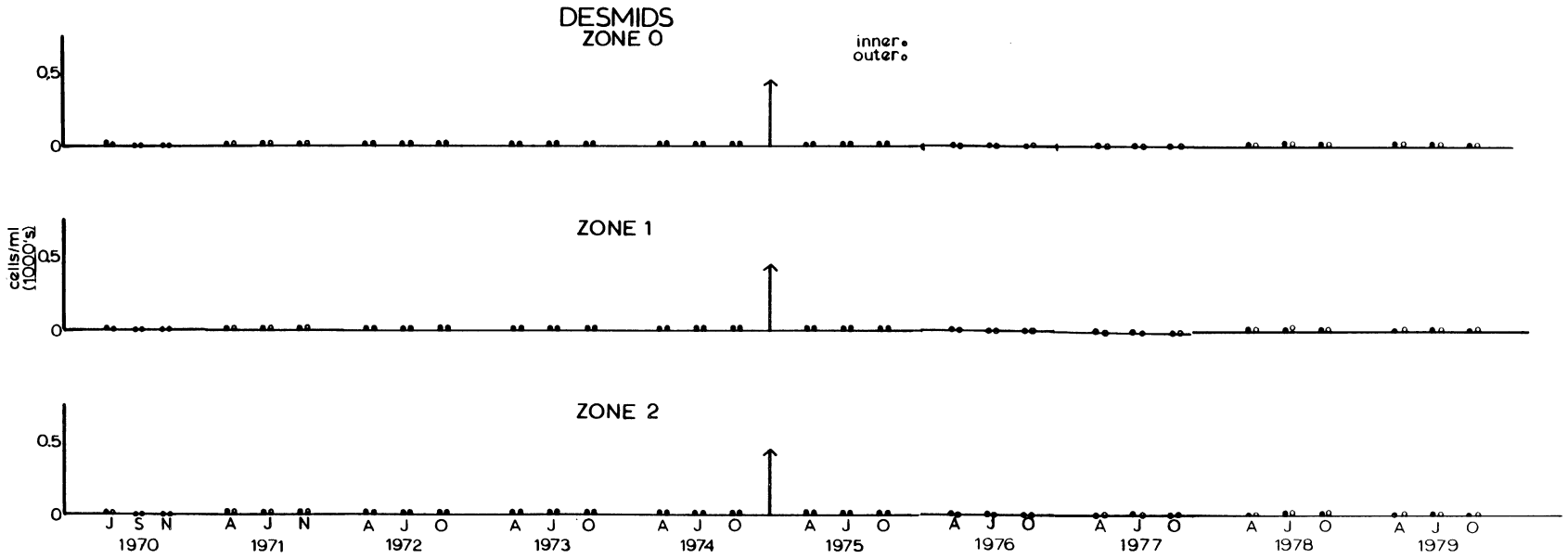

FIG. 4A. Mean abundances of desmids in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. Space does not permit the drawing of standard error bars.
See Table 6 for standard errors and numbers of observations.

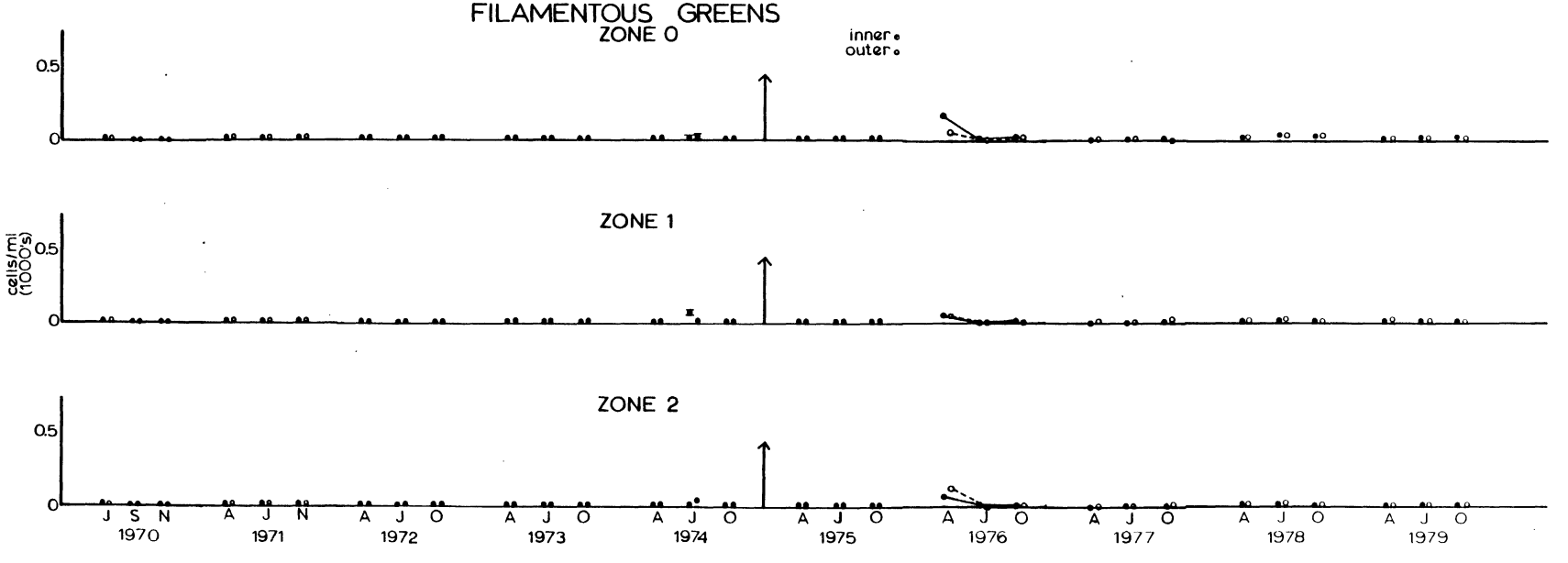

FIG. 4B. Mean abundances of filamentous green algae in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. Space does not permit the drawing of standard error bars. See Table 6 for standard errors and numbers of observations.

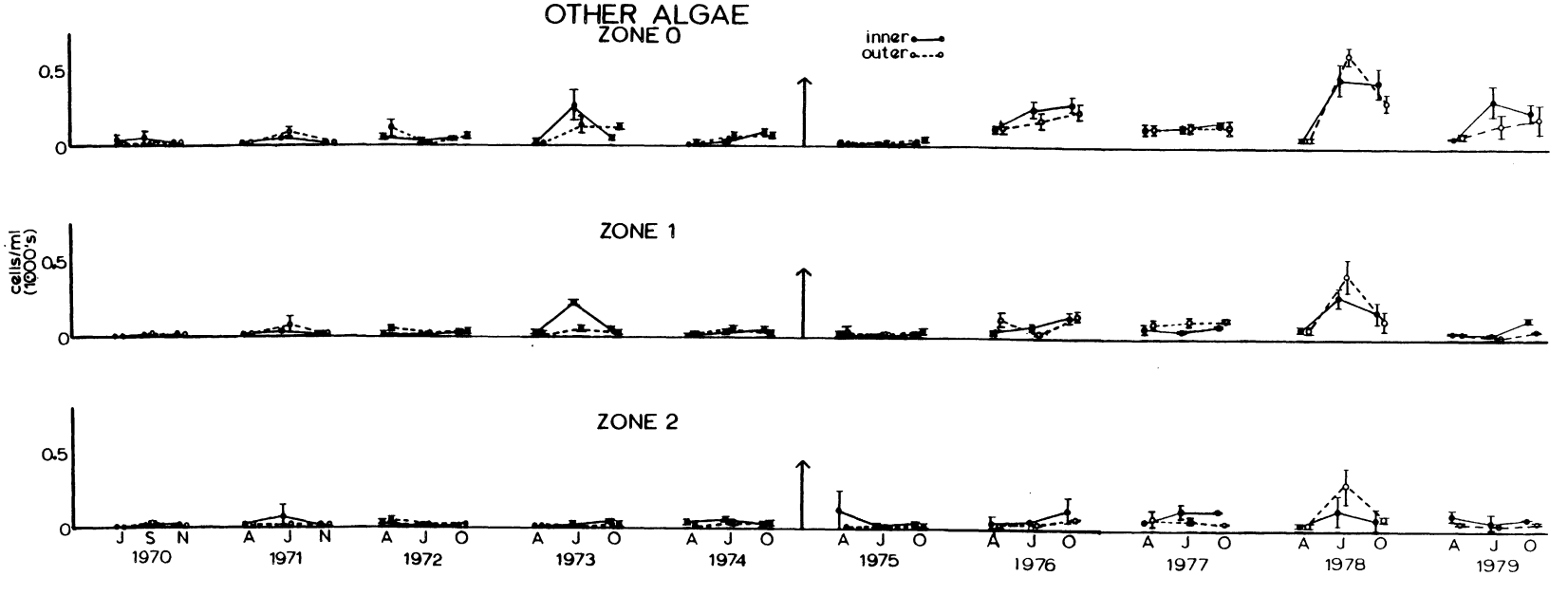

FIG. 4C. Mean abundances of "other algae" in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

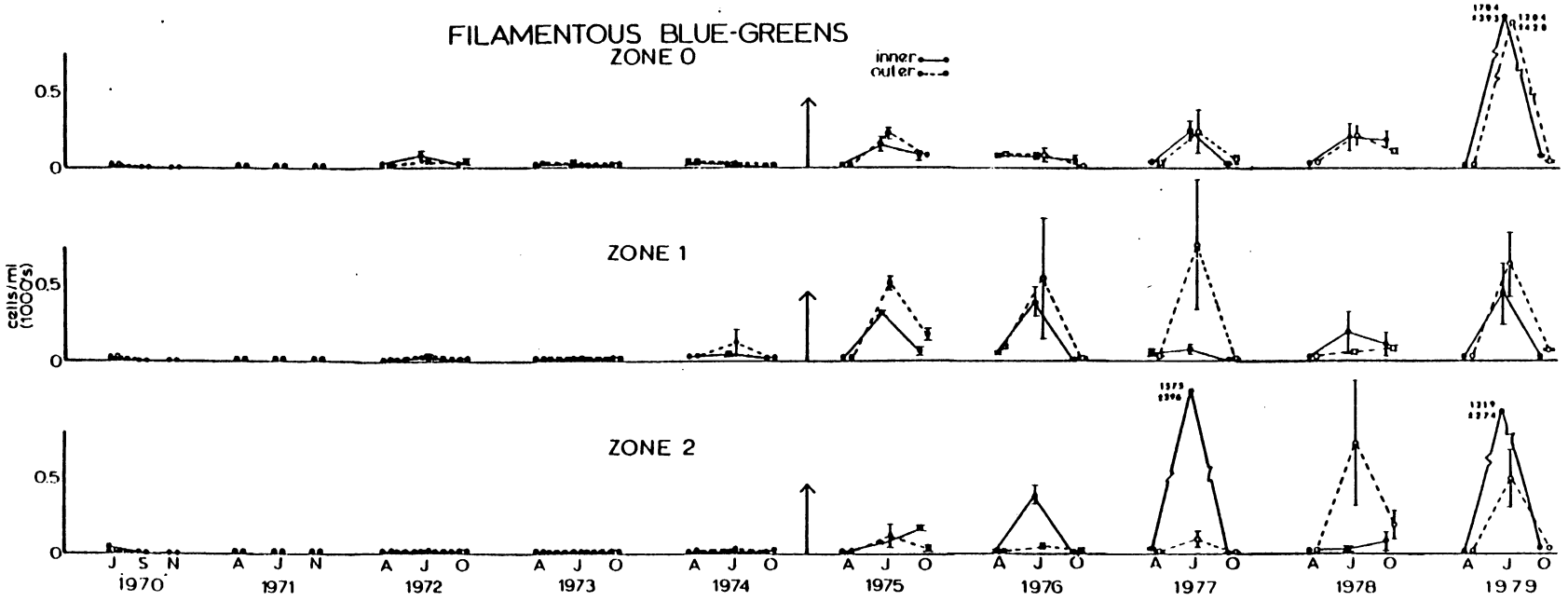

FIG. 4D. Mean abundances of filamentous blue-green algae in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. Where space permits, vertical bars show the standard errors. See Table 6 for other standard errors and for numbers of observations.

discharge plume is present little if any of the time; the increases at these stations appear more apt to be effects of lake eutrophication than of Cook Plant operation.

Coccoid blue-greens (Fig. 4E), which had been present in small amounts during most of the preoperational surveys, increased notably in October of preoperational 1974 (due in part to a change in counting method that year) and this pattern has been characteristic in the years since, not so pronounced in 1976, and very pronounced in 1977. It is to be noted that the increases in October 1977 were greater in the outer stations of zones 1 and 2. Beginning in preoperational 1974 and continuing since, these fall increases are attributed to lake eutrophication, rather than to plant operation.

Coccoid green algae (Fig. 4F) have been present in variable abundances of a few hundred cells per mL in each survey of the study area. In all but one of the operational surveys the abundances of these algae were at levels which had been observed in the preoperational years; the exception was at the inner station group of zone 2 in July 1977 when abundances were somewhat higher than previously seen. These being offshore stations where the plant plume is not expected, the high of that month is attributed to some lake effect, not plant operation.

Flagellates (Fig. 4G) in all depth zones and both station groups increased from 1971 through 1977, but began to decrease in 1978 and continued the decrease in 1979. The cause of the decrease is not known at this time; as it occurred at outer stations as well as at inner ones it is attributed to some condition in the lake and not to plant operation.

Pennate diatoms (Fig. 4H), which had maintained generally rising trends from 1971 through 1977, also began to decline in 1978 and continued to do so in

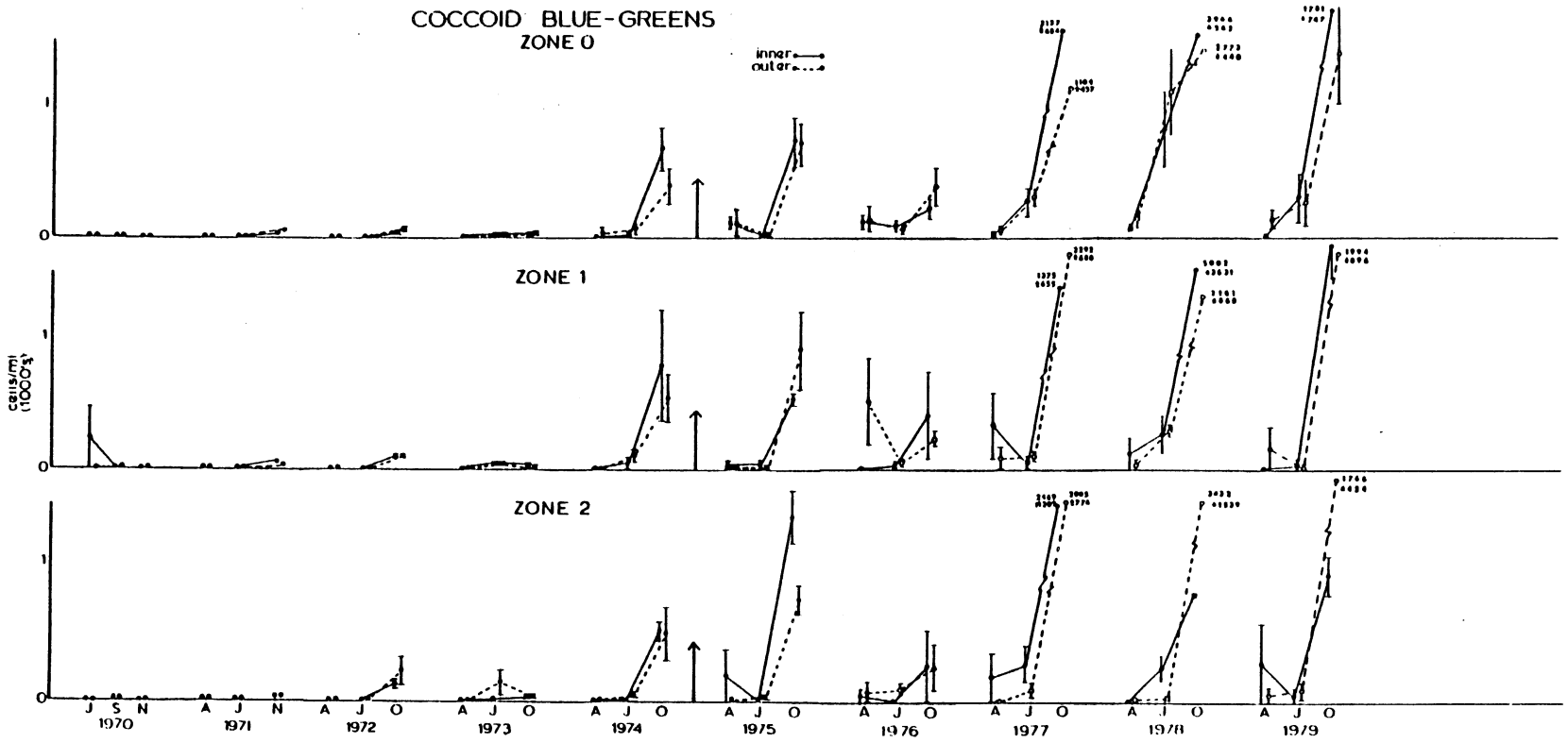

FIG. 4E. Mean abundances of coccoid blue-green algae in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. Vertical bars show the standard errors. See Table 6 for numbers of observations.

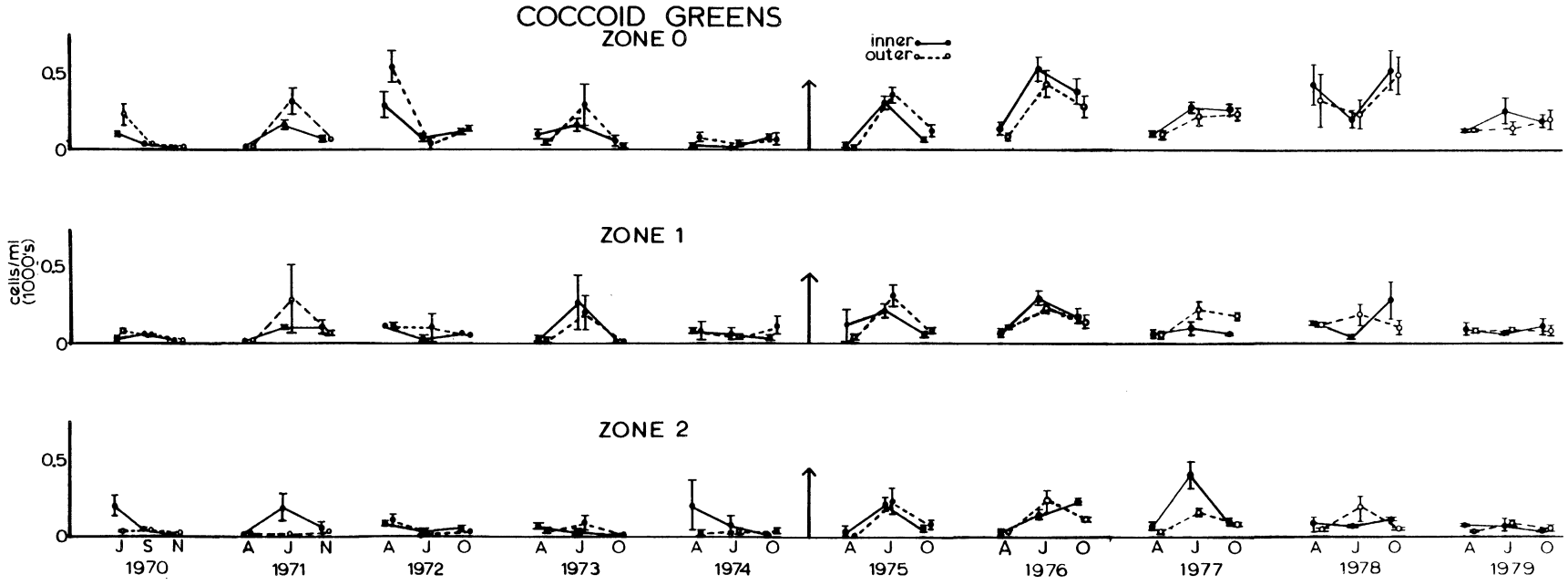

FIG. 4F. Mean abundances of coccoid green algae in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

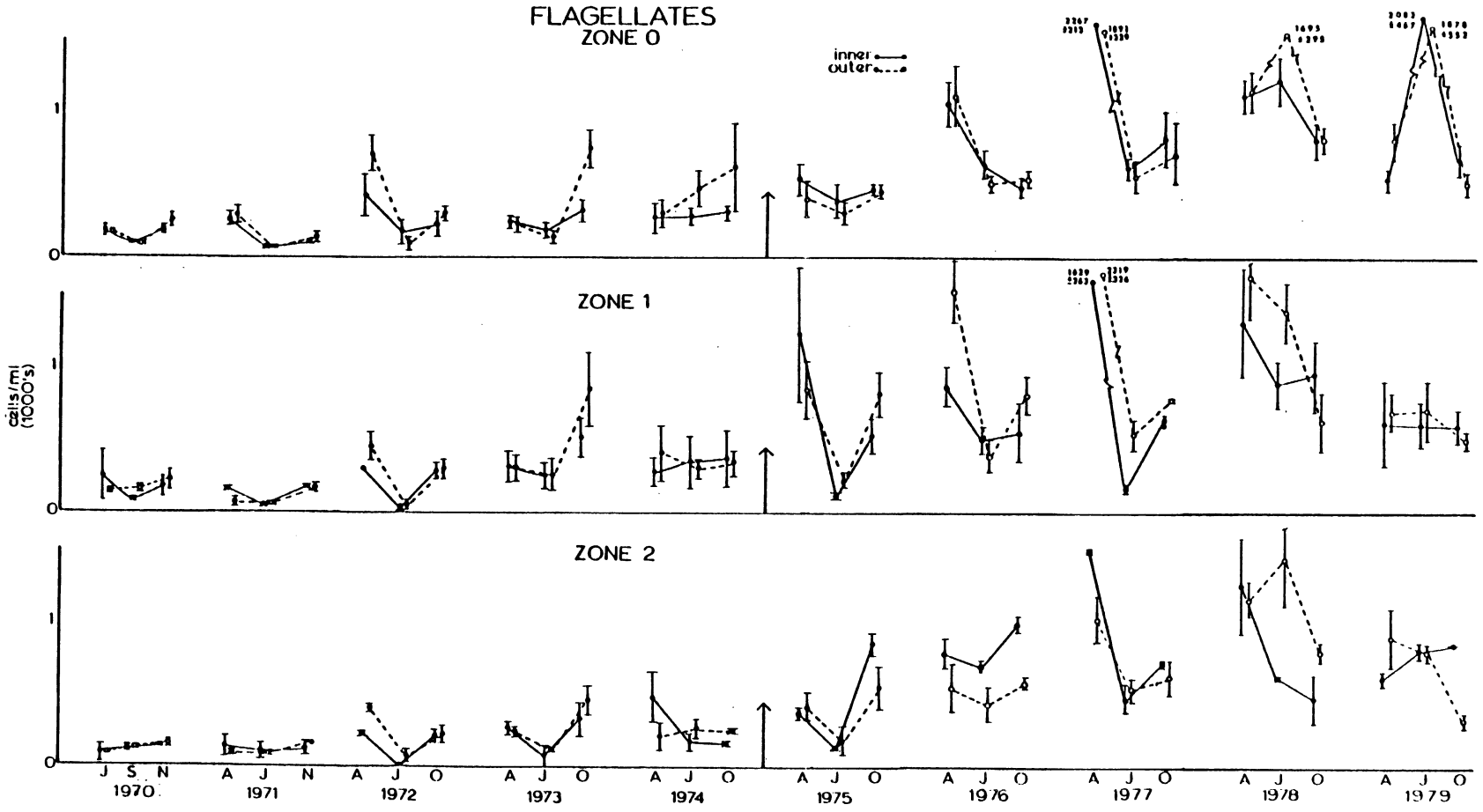

FIG. 4G. Mean abundances of flagellates in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

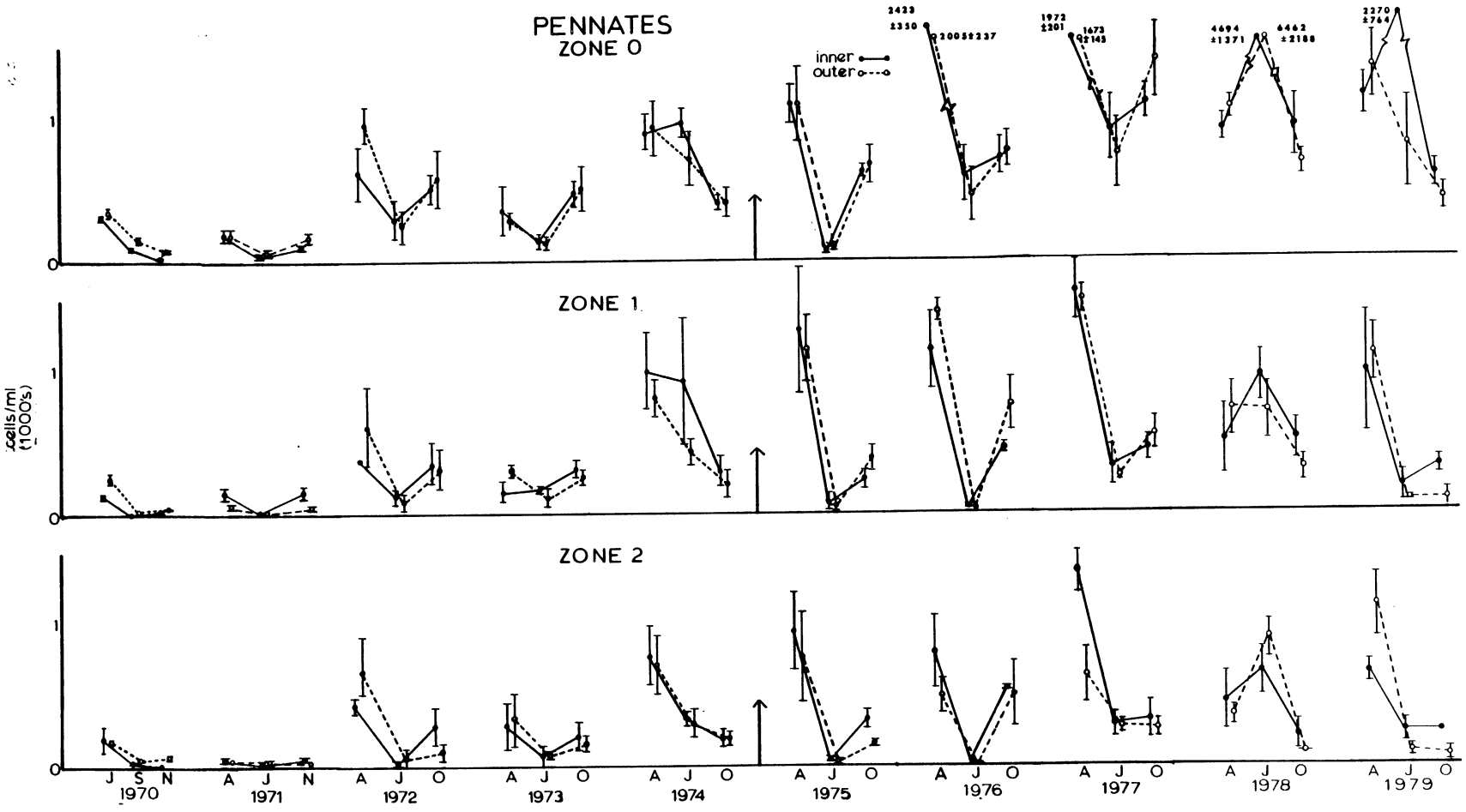

FIG. 4H. Mean abundances of pennate diatoms in zones 0 - 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

1979. The decrease is pronounced in zones 1 and 2 in summer and fall; at present it is attributed to summer and fall depletions of silica in the main body of the lake. As the decrease occurred at both inner and outer stations, it is not considered an effect of plant operation.

Centric diatoms (Figs. 4I, 4J, 4K) have varied widely in abundance during the period of study. Abundance variations at inner and outer stations have been directionally similar within each year but the annual patterns have been inconsistent from year to year. No clear effect of plant operation is shown by centric diatoms.

Total algae (Figs. 4L, 4M, 4N) had, with the exception of zone 2 inner stations in 1978, exhibited steadily rising trends in abundance since 1974. These were not continued in 1979; although abundances remained high they were below those of 1978. Declines in abundances of flagellates, pennate diatoms, and centric diatoms not completely offset by continuing increases in blue-green algae are considered the reason for lower abundances in 1979.

Inner-Outer Statistical Comparison: Phytoplankton Abundances by Algal Categories

Ayers (1978) and Ayers and Wiley (1979) have reported statistical tests for significant differences in phytoplankton abundances at the inner and outer station groups in the years 1970 through 1977; this section extends the testing to cover the years 1978 and 1979. The test used is the Student's *t* test applied to the seasonal mean abundances in the inner vs. the outer stations.

The strategy was that if plant-caused effects on the phytoplankton were present they might be expected to show as consistent significant differences in abundance between the inner and outer stations. A corollary to this was that

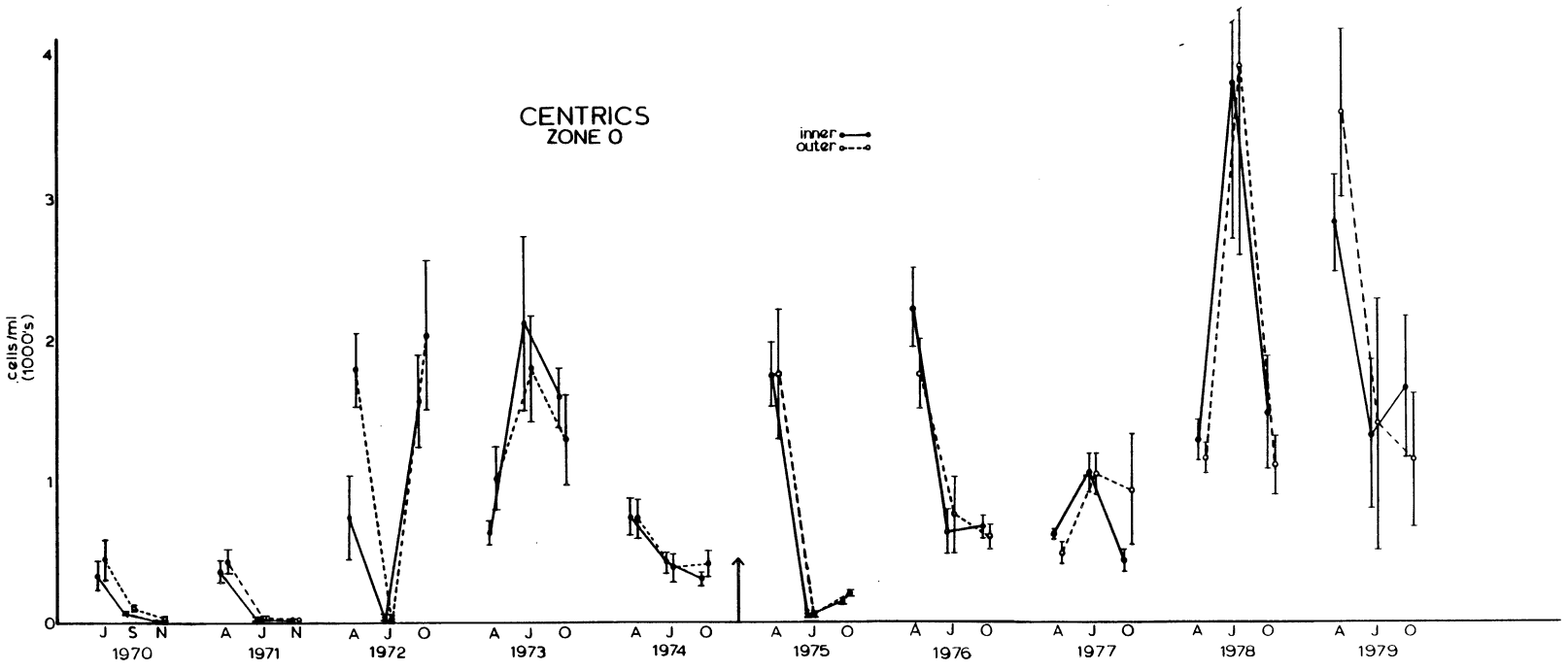

FIG. 4I. Mean abundances of centric diatoms in zone 0 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

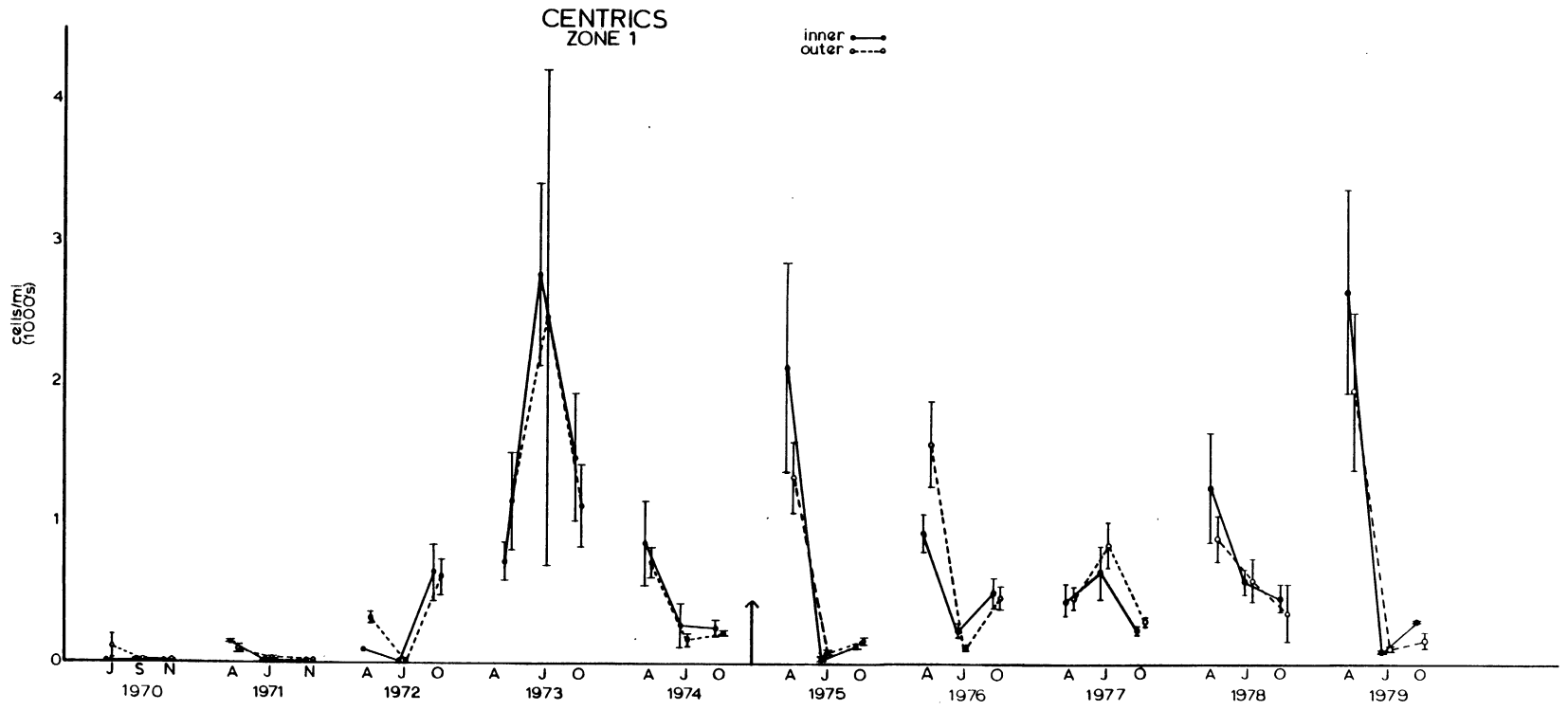

FIG. 4J. Mean abundances of centric diatoms in zone 1 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

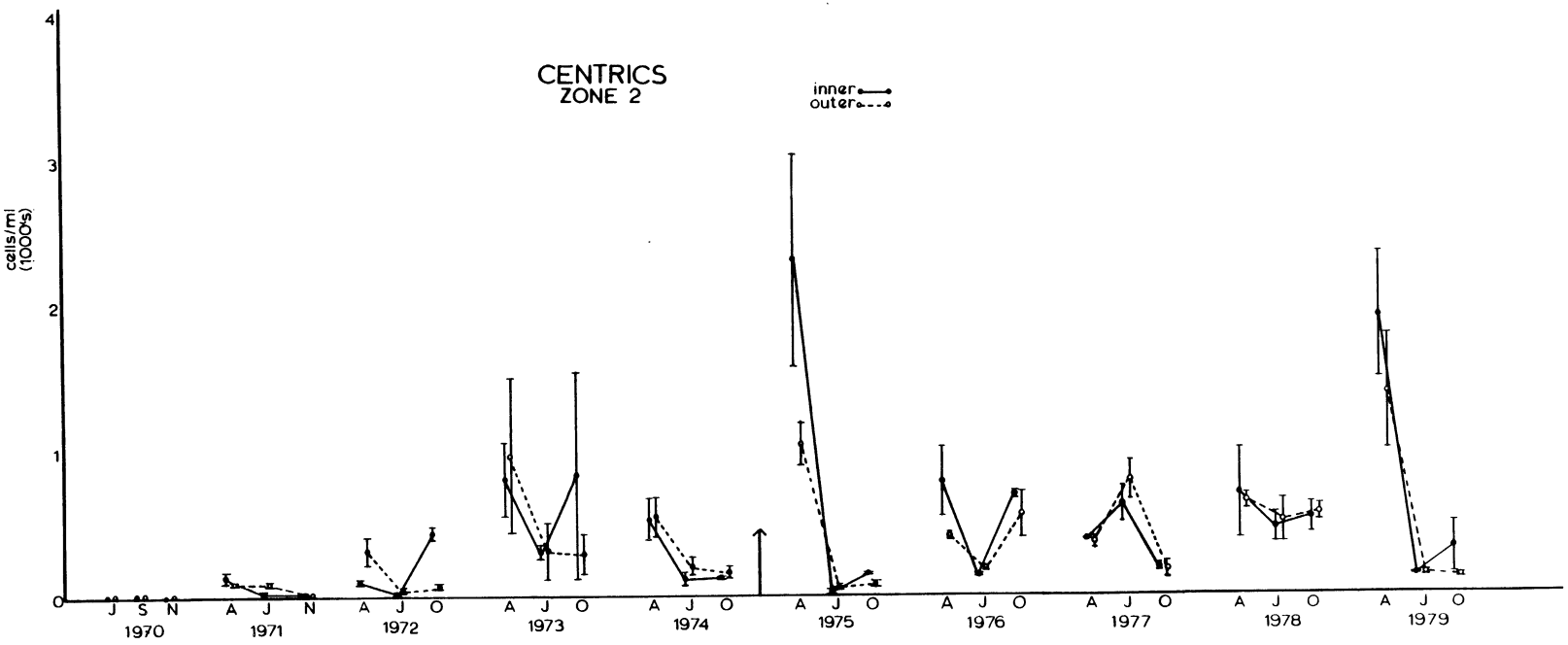

FIG. 4K. Mean abundances of centric diatoms in zone 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

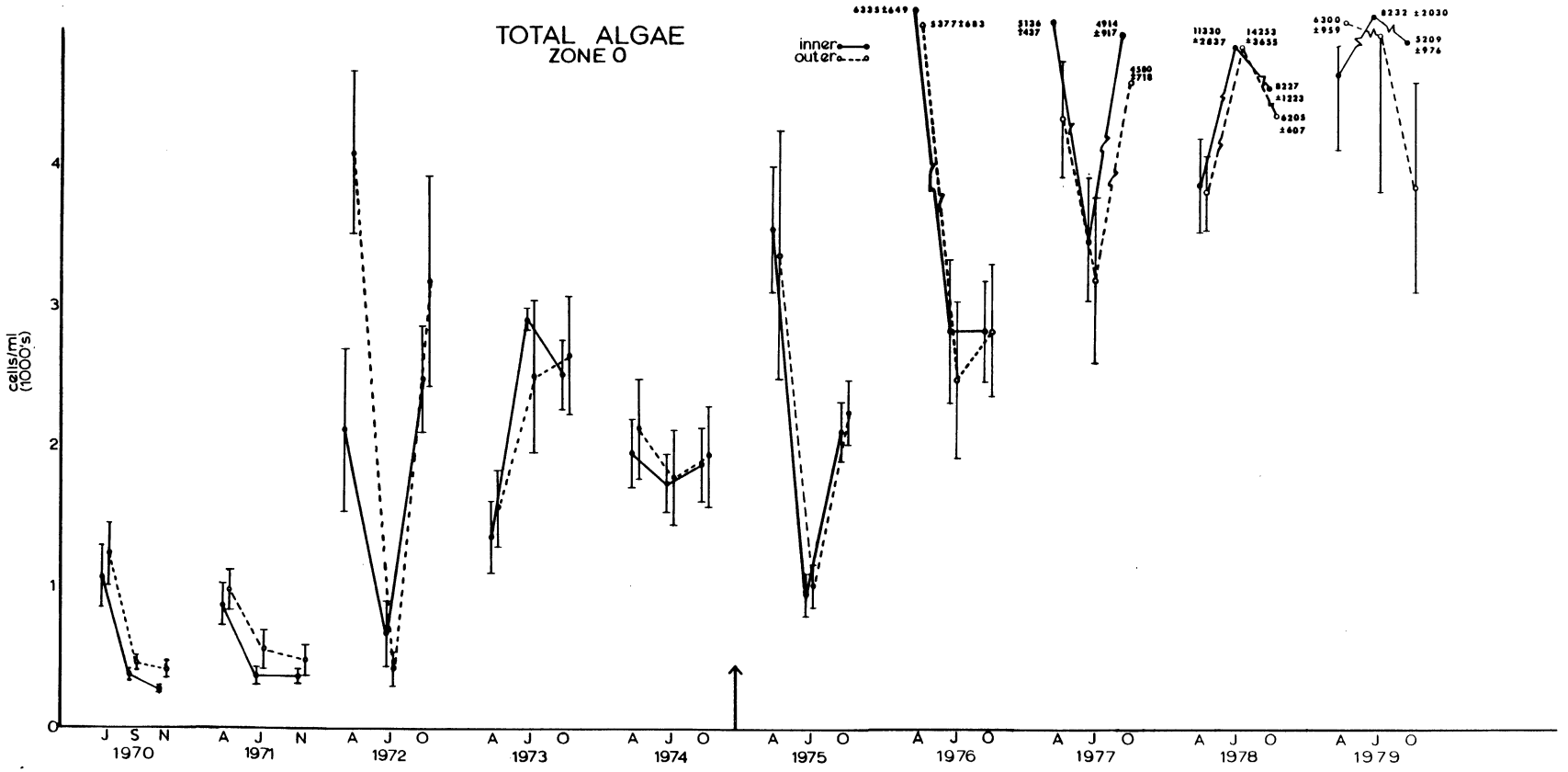

FIG. 4L. Mean abundances of total algae in zone 0 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

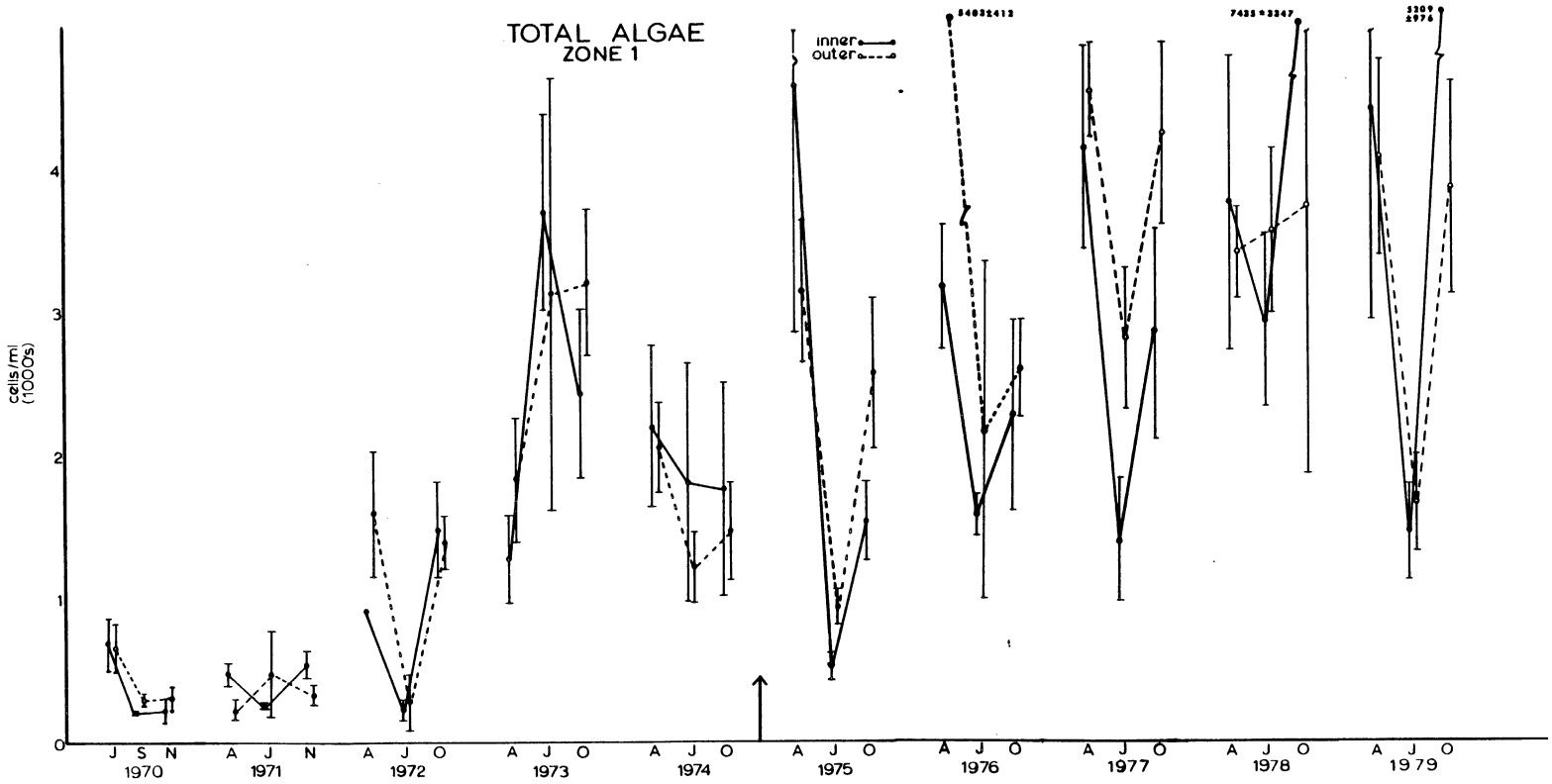

FIG. 4M. Mean abundances of total algae in zone 1 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

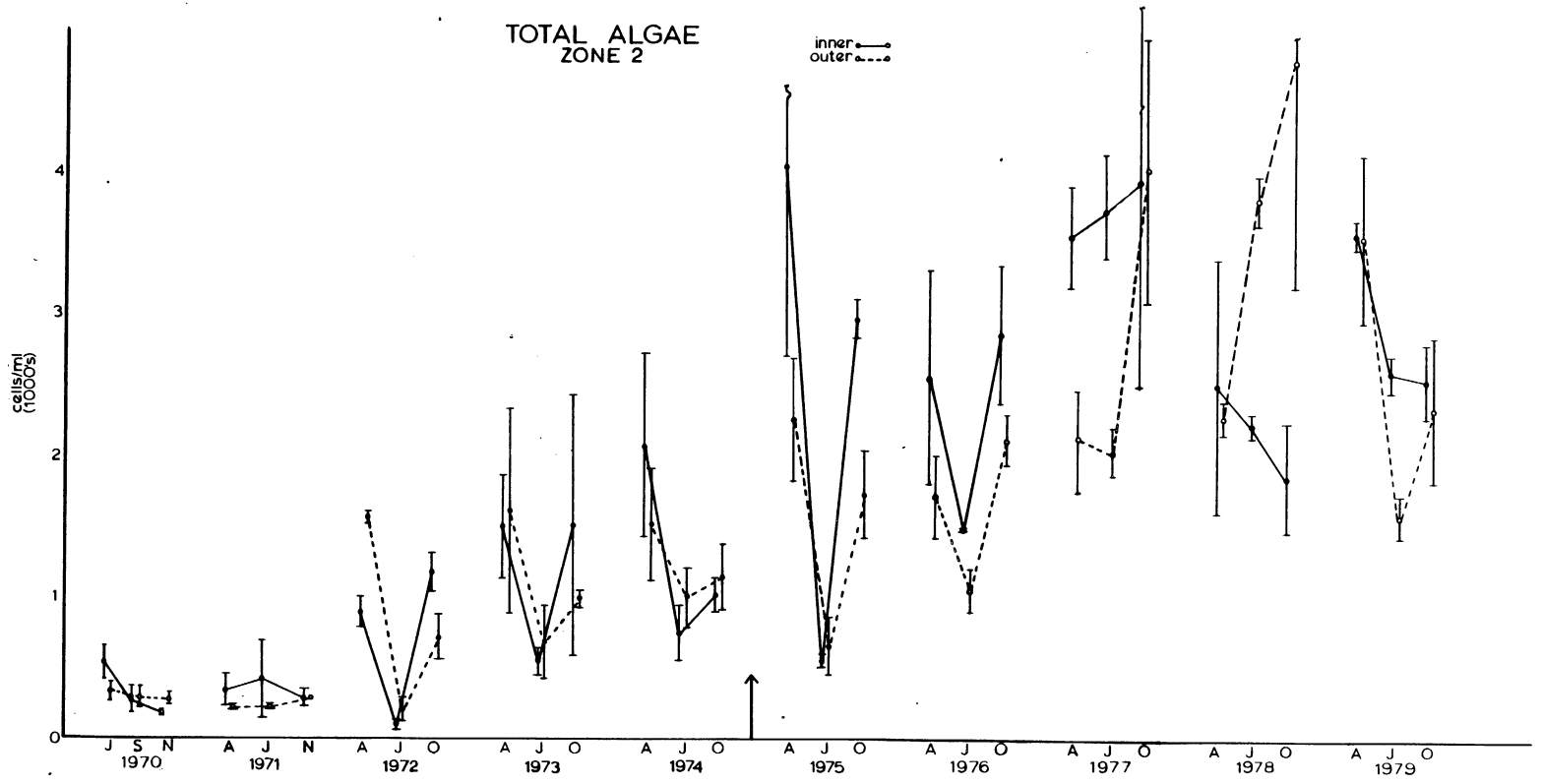

FIG. 4N. Mean abundances of total algae in zone 2 in the spring, summer, and fall seasonal surveys of 1970 through 1979. The vertical bars show the standard errors.
See Table 6 for numbers of observations.

plant operation might selectively act uupon only one or a few of the ten categories of algae, producing consistent significant differences between abundances of the affected categories at inner and outer stations.

For these tests spring was defined as April; summer as July; and fall as October. For each season in each depth zone all available abundances of each algal category were averaged to give seasonal mean abundances at the inner and outer stations of each depth zone, and comparisons were made between inner and outer mean abundances of each category in each depth zone.

Table 7 summarizes the means, variance, numbers of observations, and t-test of significance for each algal category in each season, station group, and depth zone during 1978 and 1979.

During the period from July 1970 through October 1979, 767 paired comparisons of inner vs. outer station group cell density means have been possible; of these, 350 were from preoperational years and 417 were from operational years. During the entire period there have been a total of 42 cases of significant differences of mean densities between inner and outer station groups; these amount to 5.5% of the possible comparisons.

The following tabulation summarizes the distribution of the cases wherein there were significant (at the .05 or .01 levels) differences between mean densities of phytoplankton categories in inner and outer station groups. In each case the order of the abbreviations is: year, depth zone, season (Sp, Su, Fa), and I or O indicating which station group had the greater mean density of cells; cases in operational years are underlined.

TABLE 7. Algal abundances (cells/ml), by algal categories, at inner (treatment) and outer (control) station groups in three depth zones in April, July, and October of 1978. In each season in each depth zone the mean count of cells/ml at inner stations is compared to that at outer stations using a two-sample t-test. Symbols used: n.s. = no significant difference between the two groups; * = significance at the .05 level; ** = significance at the .01 level; N = the number of stations for which data were available. No test was made if one of the groups contained only a single observation, or if one of the group variances was zero.

Survey	Station group	Zone 0 (0-8m) Means	Variance	N	t-test	Zone 1 (8-16m) Means	Variance	N	t-test	Zone 2 (16-24m) Means	Variance	N	t-test
COCCOID BLUE-GREEN ALGAE													
Spring	Inner	55.825	11445.0	12	0.2051 n.s.	116.07	40414.0	3	0.4172 n.s.	0	0	2	----
	Outer	138.62	34446.0	10		26.525	2376.50	4		37.300	5565.20	4	
Summer	Inner	803.32	$.91512 \times 10^6$	12	0.5175 n.s.	259.77	53979.0	3	0.8106 n.s.	248.70	19800.0	2	0.0301 *
	Outer	1082.4	$.10561 \times 10^7$	10		290.57	6518.50	4		21.550	1857.60	4	
Fall	Inner	3966.6	$.35348 \times 10^7$	12	0.1123 n.s.	5002.9	$.20763 \times 10^8$	3	0.2978 n.s.	798.40	2782.60	2	0.3175 n.s.
	Outer	2772.9	$.19391 \times 10^7$	10		2181.0	$.30137 \times 10^7$	4		3432.2	$.94720 \times 10^7$	4	
FILAMENTOUS BLUE-GREEN ALGAE													
Spring	Inner	3.5833	42.843	12	0.5798 n.s.	5.5333	47.963	3	0.7283 n.s.	13.250	198.00	2	0.2435 n.s.
	Outer	4.9600	20.149	10		4.1250	9.9825	4		4.5500	6.0300	4	
Summer	Inner	196.62	$.10318 \times 10^6$	12	0.9797 n.s.	170.77	58255.0	3	0.3497 n.s.	36.450	1235.0	2	0.5398 n.s.
	Outer	199.61	36919.0	10		49.750	505.35	4		463.00	$.72112 \times 10^6$	4	
Fall	Inner	170.09	24797.0	12	0.2551 n.s.	99.467	16368.0	3	0.7181 n.s.	74.600	5283.90	2	0.4651 n.s.
	Outer	106.61	5278.9	10		72.100	3743.9	4		177.02	26905.0	4	
COCCOID GREEN ALGAE													
Spring	Inner	417.28	$.24661 \times 10^6$	12	0.6564 n.s.	123.80	355.75	3	0.5130 n.s.	73.750	3034.2	2	0.3583 n.s.
	Outer	317.04	$.29561 \times 10^6$	10		114.02	314.01	4		41.875	668.01	4	
Summer	Inner	189.85	36735.0	12	0.6388 n.s.	43.633	2698.8	3	0.1916 n.s.	58.850	1496.0	2	0.3451 n.s.
	Outer	238.76	82782.0	10		173.25	19268.0	4		177.82	21507.0	4	
Fall	Inner	507.49	$.17742 \times 10^6$	12	0.8545 n.s.	264.20	48665.0	3	0.1864 n.s.	104.50	269.12	2	0.0651 n.s.
	Outer	476.53	$.11982 \times 10^6$	10		89.950	4581.1	4		42.250	992.25	4	
FILAMENTOUS GREEN ALGAE													
Spring	Inner	3.8667	179.41	12	0.6233 n.s.	1.1000	3.6300	3	0.2848 n.s.	0	0	2	----
	Outer	1.6600	17.803	10		6.6500	58.963	4		2.4750	24.502	4	
Summer	Inner	23.758	760.24	12	0.5135 n.s.	12.133	102.74	3	0.2856 n.s.	9.1000	165.62	2	0.3527 n.s.
	Outer	31.830	855.13	10		26.525	345.86	4		19.875	131.78	4	
Fall	Inner	3.5917	32.999	12	0.4869 n.s.	4.4000	14.520	3	0.9293 n.s.	0	0	2	----
	Outer	5.4600	43.978	10		4.9750	99.002	4		0.4250	0.7225	4	
FLAGELLATES													
Spring	Inner	1180.3	$.14518 \times 10^6$	12	0.7007 n.s.	1272.8	$.41512 \times 10^6$	3	0.5035 n.s.	1243.5	$.22883 \times 10^6$	2	0.3211 n.s.
	Outer	1114.2	$.17026 \times 10^6$	10		1592.6	$.28594 \times 10^6$	4		1154.8	59453.0	4	
Summer	Inner	1182.1	$.31511 \times 10^6$	12	0.1262 n.s.	869.93	761.21	3	0.1459 n.s.	613.50	1984.5	2	0.1746 n.s.
	Outer	1695.1	$.87176 \times 10^6$	10		1309.9	$.18623 \times 10^6$	4		1448.7	$.45559 \times 10^6$	4	
Fall	Inner	774.04	$.13177 \times 10^6$	12	0.9293 n.s.	927.43	$.16472 \times 10^6$	3	0.3431 n.s.	473.35	45030.0	2	0.0637 n.s.
	Outer	786.32	69216.0	10		611.15	$.15097 \times 10^6$	4		786.75	11967.0	4	

TABLE 7 continued.

Survey	Station group	Zone 0 (0-8m) Means	Variance	N	t-test	Zone 1 (8-16m) Means	Variance	N	t-test	Zone 2 (16-24m) Means	Variance	N	t-test
CENTRIC DIATOMS													
Spring	Inner	1273.4	$.24333 \times 10^6$	12	0.4912 n.s.	1250.2	$.44900 \times 10^6$	3	0.3998 n.s.	682.30	$.17916 \times 10^6$	2	0.8295 n.s.
	Outer	1146.4	$.10010 \times 10^6$	10		910.25	$.90795 \times 10^6$	4		636.67	10316.0	4	
Summer	Inner	3780.9	$.17054 \times 10^8$	12	0.9372 n.s.	579.80	15398.0	3	0.9127 n.s.	450.20	20120.0	2	0.8614 n.s.
	Outer	3923.3	$.17777 \times 10^8$	10		599.37	72017.0	4		491.60	81220.0	4	
Fall	Inner	1471.5	$.20157 \times 10^7$	12	0.4622 n.s.	472.03	25472.0	3	0.6866 n.s.	121.00	16635.0	2	0.7631 n.s.
	Outer	1107.6	$.39296 \times 10^6$	10		360.22	$.17820 \times 10^6$	4		149.22	8060.6	4	
PENNATE DIATOMS													
Spring	Inner	884.31	$.11188 \times 10^6$	12	0.2460 n.s.	919.70	$.11544 \times 10^6$	3	0.4461 n.s.	444.35	73997.0	2	0.5247 n.s.
	Outer	1035.3	56699.0	10		692.65	$.13682 \times 10^6$	4		345.27	11341.0	4	
Summer	Inner	4693.8	$.22558 \times 10^8$	12	0.4867 n.s.	727.33	$.30929 \times 10^6$	3	0.9021 n.s.	646.65	50657.0	2	0.3299 n.s.
	Outer	6461.8	$.47874 \times 10^8$	10		682.72	$.13312 \times 10^6$	4		871.72	56451.0	4	
Fall	Inner	910.13	$.55126 \times 10^6$	12	0.3240 n.s.	497.43	63080.0	3	0.2062 n.s.	192.30	21136.0	2	0.1756 n.s.
	Outer	659.25	72211.0	10		282.07	20790.0	4		86.625	30236.0	4	
DESMIDS													
Spring	Inner	0.5500	1.6500	12	0.6685 n.s.	1.1000	3.6300	3	0.8457 n.s.	0	0	2	----
	Outer	0.3300	1.0890	10		0.8250	2.7225	4		0	0	4	
Summer	Inner	8.4250	115.82	12	0.9773 n.s.	0.5667	0.9633	3	0.2641 n.s.	1.6500	5.4450	2	0.5057 n.s.
	Outer	8.2800	164.40	10		4.5500	28.030	4		3.3000	7.2600	4	
Fall	Inner	2.7583	21.641	12	0.2850 n.s.	1.1000	3.6300	3	0.3871 n.s.	0.8500	1.4450	2	1.0000 n.s.
	Outer	0.9900	4.9610	10		0.2000	0.1600	4		0.8500	0.9633	4	
OTHER ALGAE													
Spring	Inner	50.525	1096.1	12	0.8721 n.s.	58.567	1161.2	3	0.8306 n.s.	29.000	1.2800	2	0.2212 n.s.
	Outer	53.050	1567.4	10		52.650	1195.0	4		36.875	52.149	4	
Summer	Inner	451.69	$.11537 \times 10^6$	12	0.2034 n.s.	271.37	7684.2	3	0.2940 n.s.	127.70	16635.0	2	0.4243 n.s.
	Outer	608.84	32125.0	10		416.17	38498.0	4		291.40	54762.0	4	
Fall	Inner	419.33	$.11628 \times 10^6$	12	0.3097 n.s.	165.80	14727.0	3	0.6514 n.s.	64.650	8359.2	2	0.2879 n.s.
	Outer	291.49	40245.0	10		118.77	17589.0	4		72.550	812.62	4	
TOTAL ALGAE													
Spring	Inner	3869.6	$.15267 \times 10^7$	12	0.8996 n.s.	3748.9	$.31440 \times 10^7$	3	0.7245 n.s.	2486.3	$.15474 \times 10^7$	2	0.7063 n.s.
	Outer	3811.5	$.63990 \times 10^6$	10		3400.2	$.40165 \times 10^7$	4		2259.9	39783.0	4	
Summer	Inner	11330.0	$.96599 \times 10^8$	12	0.5284 n.s.	2935.4	$.10746 \times 10^7$	3	0.4985 n.s.	2192.8	11889.0	2	0.0032 **
	Outer	14253.0	$.13357 \times 10^9$	10		3552.8	$.13311 \times 10^7$	4		3789.1	$.10876 \times 10^6$	4	
Fall	Inner	8227.3	$.18105 \times 10^8$	12	0.1812 n.s.	7434.7	$.33606 \times 10^8$	3	0.3058 n.s.	1829.7	$.29215 \times 10^6$	2	0.2879 n.s.
	Outer	6205.4	$.36876 \times 10^7$	10		3720.5	$.79049 \times 10^7$	4		4747.8	$.99987 \times 10^7$	4	

TABLE 7 . Algal abundances(cells/ml), by algal categories, at inner (treatment) and outer (control) station groups in three depth zones in April, July, and October of 1979. In each season in each depth zone the mean count of cells/ml at inner stations is compared to that at outer stations using a two-sample t-test. Symbols used: n.s. = no significant difference between the two groups; * = significance at the .05 level; ** = significance at the .01 level; N = the number of stations for which data were available. No test was made if one of the groups contained only a single observation, or if one of the group variances was zero.

Survey	Station group	Zone 0 (0-8m) Means	Variances	N	t-test	Zone 1 (8-16m) Means	Variances	N	t-test	Zone 2 (16-24m) Means	Variances	N	t-test
COCCOID BLUE-GREEN ALGAE													
Spring	Inner	14.367	1453.2	12	0.0448*	0	0	3		285.20	0.16268×10^{6}	2	0.2924 n.s.
	Outer	141.28	40825.0	10		165.80	0.10996×10^{6}	4		56.375	9196.9	4	
Summer	Inner	301.91	0.36504×10^{6}	12	0.8678 n.s.	40.900	2710.0	3	0.7914 n.s.	58.050	6739.6	2	0.7365 n.s.
	Outer	261.14	0.26248×10^{6}	10		29.025	3369.8	4		91.175	12734.0	4	
Fall	Inner	1781.4	0.67001×10^{7}	12	0.6500 n.s.	1749.3	0.17921×10^{6}	3	0.8398 n.s.	960.05	39734.0	2	0.2776 n.s.
	Outer	1370.9	0.14371×10^{7}	10		1993.8	0.32105×10^{7}	4		1766.1	0.71953×10^{6}	4	
FILAMENTOUS BLUE-GREEN ALGAE													
Spring	Inner	2.4750	14.107	12	0.6159 n.s.	0	0	3		0	0	2	
	Outer	3.3000	14.520	10		4.1250	9.9825	4		5.8000	54.260	4	
Summer	Inner	1704.5	0.18559×10^{7}	12	0.4003 n.s.	442.70	0.12735×10^{6}	3	0.5928 n.s.	1219.5	0.15059×10^{6}	2	0.0793 n.s.
	Outer	1204.4	0.18357×10^{7}	10		610.40	0.16172×10^{6}	4		484.15	0.12520×10^{6}	4	
Fall	Inner	66.883	9828.9	12	0.3403 n.s.	22.667	391.58	3	0.0703 n.s.	48.100	4627.2	2	0.9757 n.s.
	Outer	34.820	1046.7	10		64.225	677.13	4		47.050	328.70	4	
COCCOID GREEN ALGAE													
Spring	Inner	130.71	14604.0	12	0.9078 n.s.	91.767	3261.7	3	0.9368 n.s.	72.950	351.13	2	0.2067 n.s.
	Outer	136.14	8135.7	10		88.700	1695.3	4		42.700	600.92	4	
Summer	Inner	245.12	89101.0	12	0.3153 n.s.	54.133	852.21	3	0.4468 n.s.	81.250	2910.8	2	0.8830 n.s.
	Outer	139.70	18060.0	10		74.000	1087.9	4		72.950	4007.5	4	
Fall	Inner	182.45	13459.0	12	0.9325 n.s.	120.50	8254.2	3	0.3837 n.s.	24.850	49.005	2	0.1236 n.s.
	Outer	177.07	31217.0	10		70.675	2282.9	4		56.400	451.11	4	
FILAMENTOUS GREEN ALGAE													
Spring	Inner	11.875	1372.0	12	0.5416 n.s.	1.1000	3.6300	3	0.4873 n.s.	0	0	2	
	Outer	4.4800	41.640	10		9.9500	396.01	4		0	0	4	
Summer	Inner	2.0750	38.707	12	0.1308 n.s.	1.1000	3.6300	3	0.3321 n.s.	3.3000	21.780	2	
	Outer	8.6300	162.43	10		4.9750	34.816	4		0	0	4	
Fall	Inner	33.442	2908.1	12	0.1408 n.s.	0	0	3		0	0	2	
	Outer	6.8000	97.960	10		0	0	4		0	0	4	
FLAGELLATES													
Spring	Inner	522.80	75028.0	12	0.0927 n.s.	636.67	0.25963×10^{6}	3	0.8532 n.s.	623.45	2197.8	2	0.3830 n.s
	Outer	785.10	0.17679×10^{6}	10		693.07	66586.0	4		895.35	0.13639×10^{6}	4	
Summer	Inner	2082.7	0.26183×10^{7}	12	0.7782 n.s.	623.73	65914.0	3	0.6957 n.s.	795.85	6350.6	2	0.2933 n.s.
	Outer	1877.6	0.30522×10^{7}	10		733.50	0.15644×10^{6}	4		693.07	10733.0	4	
Fall	Inner	667.08	0.13688×10^{6}	12	0.2025 n.s.	603.00	33496.0	3	0.4010 n.s.	847.25	5.4450	2	0.0003**
	Outer	490.44	50506.0	10		505.90	9680.3	4		272.97	4542.0	4	

TABLE 7 continued.

Survey	Station group	Zone 0 (0-8m) Means	Variances	N	t-test	Zone 1 (8-16m) Means	Variances	N	t-test	Zone 2 (16-24m) Means	Variances	N	t-test
CENTRIC DIATOMS													
Spring	Inner	2822.8	0.14347×10^7	12	0.2573 n.s.	2627.5	0.15750×10^7	3	0.4710 n.s.	1880.3	0.36594×10^6	2	0.4412 n.s.
	Outer	3581.1	0.33715×10^7	10		1934.9	0.12057×10^7	4		1354.6	0.55124×10^6	4	
Summer	Inner	1314.4	0.33921×10^7	12	0.1885 n.s.	84.567	1174.3	3	0.5810 n.s.	112.75	136.13	2	0.8118 n.s.
	Outer	485.16	0.35159×10^6	10		104.02	2327.5	4		118.95	1011.3	4	
Fall	Inner	1649.6	0.29365×10^7	12	0.4595 n.s.	302.33	787.26	3	0.0551 n.s.	331.65	48578.0	2	0.0867 n.s.
	Outer	1131.0	0.21397×10^7	10		165.40	8110.2	4		92.425	3732.4	4	
PENNATE DIATOMS													
Spring	Inner	1082.7	0.22897×10^6	12	0.0874 n.s.	959.47	0.52958×10^6	3	0.7709 n.s.	686.40	7938.0	2	0.2890 n.s.
	Outer	1567.5	0.60192×10^6	10		1086.0	0.13123×10^6	4		1111.3	0.21251×10^6	4	
Summer	Inner	2269.6	0.69953×10^7	12	0.1108 n.s.	171.07	25629.0	3	0.3675 n.s.	241.25	13464.0	2	0.5050 n.s.
	Outer	788.17	0.10061×10^7	10		87.900	3062.3	4		67.975	2488.8	4	
Fall	Inner	586.67	85114.0	12	0.2201 n.s.	303.97	10344.0	3	0.0252*	232.10	0	2	
	Outer	426.20	90760.0	10		85.175	6826.9	4		50.900	5082.5	4	
DESMIDS													
Spring	Inner	1.6583	17.041	12	0.8202 n.s.	0	0	3		0	0	2	
	Outer	1.3200	5.3240	10		2.4750	9.9825	4		0.4250	0.72250	4	
Summer	Inner	6.4917	21.343	12	0.7427 n.s.	0.2667	0.2133	3	0.3543 n.s.	0	0	2	
	Outer	5.6500	51.403	10		1.2500	2.5100	4		0.8500	0.96333	4	
Fall	Inner	0	0	12		0.5667	0.9633	3		0	0	2	
	Outer	1.5700	7.3334	10		0	0	4		0	0	4	
OTHER ALGAE													
Spring	Inner	63.000	2228.9	12	0.4433 n.s.	77.400	2797.5	3	0.9093 n.s	82.900	2664.5	2	0.3774 n.s.
	Outer	79.420	2617.3	10		72.950	2073.3	4		48.925	1197.9	4	
Summer	Inner	305.49	0.12614×10^6	12	0.2128 n.s.	32.333	246.90	3	0.3226 n.s.	62.150	3034.2	2	0.2800 n.s.
	Outer	141.03	43789.0	10		21.150	132.26	4		31.075	90.429	4	
Fall	Inner	241.59	47966.0	12	0.7745 n.s.	140.40	3463.8	3	0.0571 n.s.	74.600	137.78	2	0.3057 n.s.
	Outer	211.73	69572.0	10		55.750	1067.8	4		44.475	1125.5	4	
TOTAL ALGAE													
Spring	Inner	4652.0	0.33360×10^7	12	0.1309 n.s.	4393.9	0.65540×10^7	3	0.8286 n.s.	3631.1	18490.0	2	0.9019 n.s.
	Outer	6299.6	0.91886×10^7	10		4058.1	0.18191×10^7	4		3515.5	0.13735×10^7	4	
Summer	Inner	8232.3	0.49436×10^8	12	0.1908 n.s.	1450.8	0.31511×10^6	3	0.6389 n.s.	2574.1	28108.0	2	0.0104*
	Outer	4911.4	0.12466×10^8	10		1666.1	0.32167×10^6	4		1560.2	78964.0	4	
Fall	Inner	5209.1	0.11428×10^8	12	0.2973 n.s.	3242.6	0.31786×10^6	3	0.8110 n.s.	2518.6	0.13897×10^6	2	0.8220 n.s.
	Outer	3850.6	0.55669×10^7	10		2941.0	0.38779×10^6	4		2330.3	0.10472×10^7	4	

Coccoid blue-greens	75,Z2,Fa,I	78,Z2,Su,I	79,Z0,Sp,0	
Filamentous blue-greens	75,Z1,Su,0	75,Z2,Fa,I	76,Z2,Su,I	77,Z2,Su,I
Coccoid greens	70,Z2,Su,I	71,Z2,Su,I	76,Z2,Fa,I	77,Z2,Su,I
Filamentous greens		None		
Flagellates	71,Z1,Su,0	72,Z2,Sp,0	73,Z1,Fa,0	74,Z2,Fa,0
	76,Z2,Fa,I	77,Z1,Su,0	77,Z1,Fa,0	79,Z2,Fa,0
Centric diatoms	72,Z1,Sp,0	72,Z1,Fa,I	75,Z1,Fa,I	75,Z1,Fa,I
Pennate diatoms	70,Z1,Su,0	71,Z2,Su,01	73,Z1,Sp,0	75,Z2,Fa,I
	79,Z1,Fa,I			
Desmids	71,Z1,Su,0	71,Z2,Su,I		
Other algae	71,Z1,Sp,0	73,Z0,Sp,I	73,Z1,Sp,I	73,Z2,Fa,I
	74,Z2,Sp,I	77,Z2,Fa,I		
Total algae	72,Z0,Sp,0	72,Z2,Sp,0	76,Z1,Sp,0	77,Z2,Su,I
	78,Z2,Su,0	79,Z2,Su,I		

Summarized by years the cases of significant differences were:

1970 (2 seasons)	2 cases	1975	6 cases
1971	6	1976	4
1972	5	1977	6
1973	5	1978	2
1974	2	1979	4

It is noted that the six cases of difference in operational 1975 and 1977 are not greater than the six that occurred in preoperational 1971; it is also noted that the fours in operational 1976 and 1979 are less than the fives that occurred in preoperational 1972 and 1973. The numbers of cases by years appear to be within the natural range of variation, and no effect of plant operation is evident.

Summarized by depth zones, with the station group having the greatest density of algae indicated, and with operational year cases underlined, the cases of significant difference were:

Zone 0	Zone 1	Zone 2
Inner greater 1 + 0	Inner greater 0 + 3	Inner greater 6 + 13
Outer greater 1 + 1	Outer greater 7 + 4	Outer greater 4 + 2

In zone 0 the cases of significant difference in abundances at inner and outer stations have been almost equally divided between preoperational and operational years. No evidence of plant operation effects shows in these data.

With the plant's thermal plume in zone 1 most of the time, the significantly greater abundances in this zone have been at the outer stations in 11 of 14 cases. In the preoperational years all seven cases were of greater abundances at the outer stations; greater abundances at the outer stations appear to be a natural feature of this depth zone. In operational years four of seven cases were of higher abundances at the outer stations, which does not gainsay greater abundances at these stations as a natural feature of the zone.

In zone 2 during the preoperational years six of ten cases of significant differences involved higher mean cell densities in the inner stations; in operational years 13 of 15 cases have been of higher abundances in the inner stations. With the plant's thermal plume in zone 1 most of the time, and with zone 2 beginning at about two kilometers off shore and continuing farther, it is unlikely that waste heat from the plant has caused the higher densities in the inner stations of this zone.

CONCLUSIONS

Phytoplankton diversities, as indicated by diversity indices, were not quite so high in zones 0 and 1 in 1979 as they had been in earlier operational years; in zone 2 the diversities for 1979 were not noticeably different from those of preceding years. In all zones diversities remain higher than in preoperational years prior to 1974. There is no evidence that operation of Cook Plant has simplified (lowered the diversity of) the phytoplankton community.

Phytoplankton redundancy is a measure of the dominance of one or a few species within a given population. Redundancy values range from 0 to 1, with a value of 1 implying that one species dominates the community. In 1979 redundancy values rose to the levels of preoperational years after a period of

steady or slowly diminishing values from 1973 through 1978. We tentatively ascribe the 1979 condition to increased relative dominance of blue-green algae when flagellates and diatoms decreased in abundance in that year.

Of the ten categories of phytoplankton, four (desmids, filamentous greens, coccoid greens, and "other algae") have shown essentially no changes in abundances during the 10 years of the study.

Four other categories (flagellates, pennate diatoms, centric diatoms, and total algae) have in shallow zone 0 exhibited steadily increasing trends since 1970. These categories, in zones 1 and 2, showed increasing trends from 1970 through 1978 but had lower abundances in 1979. The abundance changes took place in both inner and outer stations.

Blue-green algae have increased in abundance during the period of the study. First indications of increase were minor rises in 1972 with substantially higher levels of coccoid blue-greens appearing in the fall of 1974 and being an autumn characteristic in later years. Occurring in all three depth zones and in both inner and outer station groups, the fall increases are attributed to late summer-autumn depletions of silica in the epilimnetic water. Filamentous blue-greens exhibiting summer peak abundances have increased since 1974; occurring in all three depth zones and in both inner and outer stations the cause of these abundance variations is adjudged to be something in the lake.

In the 10 years of the study there have been 767 paired comparisons of inner vs. outer station group cell density means. These have been compared by a two-sample t-test for significant differences of the means. During the entire period there have been 42 cases of significant differences between the means; these amount to 5.5% of the comparisons. The cases of differences are spread through nine of the ten categories of phytoplankton and fall within the natural

range of variation; the signifcant differences are attributed to normal accidents of sampling; no evidence of plant operation effects are shown by these analyses.

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